SOIL SALINITY AND IRRIGATION IN THE SOVIET UNION

REPORT OF A TECHNICAL STUDY GROUP

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

Foreword

An agreement was concluded on December 1, 1959, between the Governments of the United States of America and the Union of Soviet Socialist Republics providing for exchanges in the cultural, technical, and educational fields. This is the second such agreement; the first was concluded in 1958.

Agriculture, which plays an important role in the national economies of the two countries, was specifically included in the agreements as a field for exchange of specialists. The U.S. Department of Agriculture accordingly sent to the Soviet Union in 1960 four technical study groups of specialists in the following subjects: Handling, storage, and transportation of grain; food processing; agricultural information and planning; and soil salinity.

The Soviet Union in turn sent to the United States in 1960 three delegations of specialists in the following subjects: Food processing; fertilizers, insecticides, and weed killers; and agricultural science and information. In 1961, three additional Soviet teams were sent in the following fields: Cereal and forage seed production; breeding and hybridization of cattle and pigs; and mechanization of cultivation and harvesting of sugar beets and potatoes.

Each United States exchange study group, on completion of its assignment, prepared a report for publication. *Soil Salinity and Irrigation in the Soviet Union* represents the report of the soil salinity exchange group and was prepared by C. A. Bower, Chairman; H. R. Haise, Joseph Legg, and R. C. Reeve, Agricultural Research Service; Rodney Carlson, Foreign Agricultural Service; H. E. Dregne, New Mexico State College; and R. S. Whitney, Colorado State University.

Reports on the exchanges have been published under the following titles: Soil and Water Use in the Soviet Union; Economic Aspects of Soviet Agriculture; Cotton in the Soviet Union; Veterinary Science in the Soviet Union; Crop Research in the Soviet Union; Farm Mechanization in the Soviet Union; Entomology in the Soviet Union; Livestock in the Soviet Union; Forestry and Forest Industry in the U.S.S.R.; Grain Marketing in the Soviet Union; Grading and Exporting Wheat in the U.S.S.R.

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SOIL SALINITY AND IRRIGATION IN THE SOVIET UNION

Report of a Technical Study Group

Introduction

Under an exchange agreement between the Governments of the United States and the Soviet Union, a technical study group, consisting of specialists in soil salinity, irrigation, drainage, agronomy, and agricultural economics, visited the Soviet Union during the period June 27 to July 29, 1960 (fig. 1). The primary purpose of the visit was to study soil salinity in the U.S.S.R., but opportunity was also afforded to study irrigation agriculture in general because of its close relation to soil salinity. Throughout the field trips, the study group had at its disposal a field

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FIGURE 1.—Itinerary of the soil salinity technical study group in the U.S.S.R. Crosshatch areas indicate lands now under irrigation; vertical lines indicate lands proposed for irrigation.

kit[1] for testing the salinity and sodium status of soils and waters (fig. 2). Thus, some of the information contained in this report is based on direct measurements made by the group (see tables in Appendix). Most of the information, however, is based on what the group observed or was told. In preparing the report, an effort has been made to indicate how the information given was obtained.

The members of the technical group were as follows: C. A. Bower, director, U.S. Salinity Laboratory, Soil and Water Conservation Research Division, Agricultural Research Service, Rodney Carlson, Agricultural Trade Policy and Analysis, Foreign Agricultural Service, U.S. Department of Agriculture; H. E. Dregne, professor of soils, New Mexico State College; H. R. Haise, soil scientist; Joseph Legg, soil scientist; and R. C. Reeve, agricultural engineer, Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture; and R. S. Whitney, head, Department of Agronomy and Soils, Colorado State University. Two members of the group, Rodney Carlson and Joseph Legg, speak the Russian language, and one member, Rodney Carlson, had visited the Soviet Union previously in 1958. C. A. Bower served as chairman of the group. The group was accompanied throughout the entire visit by Samuel R. Offengenden, head of the Section for the Design of Irrigation Projects, Division of Water Economy, U.S.S.R. Ministry of Agriculture, and by Miss Lydia Koneva of the U.S.S.R. Exposition of Economic Achievement. Mr. Offengenden was in charge of all tours and handled all necessary arrangements, and Miss Koneva served ably as interpreter. The friendly assistance given the study group by Mr. Offengenden and Miss Koneva is gratefully acknowledged.

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FIGURE 2.—U.S. delegate demonstrating portable conductivity bridge for measuring salinity.

[1] RICHARDS, L. A., BOWER, C. A., and FIREMAN, MILTON. TESTS FOR SALINITY AND SODIUM STATUS OF SOIL AND OF IRRIGATION WATER. U.S. Dept. Agr. Cir. 982, 19 pp., illus. 1956.

Itinerary

June 24	Departure from the United States.
June 25	Arrival in Stockholm, Sweden.
June 27	Arrival in Moscow, U.S.S.R.
June 28	Conference with officials at the U.S.S.R. Ministry of Agriculture. Visit to Exposition of Economic Achievement.
June 29	Timiryazev Agricultural Academy, including the Kostyakov All-Union Institute of Hydrotechnics and Amelioration and the Williams Soil-Agronomy Museum.
June 30	Dokuchayev Institute of Soil Science, Moscow State University Department of Soil Science and Biology.
July 1	All-Union Scientific Research Institute of Fertilizers and Agricultural Soil Science at Timiryazev Agricultural Academy.
July 2	Departure for Baku, Azerbaijan S.S.R.
July 3	Trip to Mugan Experimental Amelioration Station.
July 4	Return to Baku.
July 5	Institute of Hydroengineering and Amelioration. Institute of Soil Science and Agrochemistry. State Institute for the Design and Planning of Irrigation Projects.
July 6	Departure for Ashkhabad, Turkmen S.S.R. Academy of Science of Turkmen S.S.R. Institute of Geology of Turkmen S.S.R. Academy of Science.
July 7	Visit to Communism collective farm.
July 8	Departure for Mary. Visit to Leninism collective farm, Mary Oblast.
July 9	Visit to Kara-Kum Canal and Getchi Gran Takyr Experimental Field of Turkmen S.S.R. Institute of Agronomy.
July 10	Departure for Chardzhou. Visit to Zhdanov and Kirov collective farms, Chardzhou Oblast.
July 11	Departure for Stalinabad, Tadzhik S.S.R.
July 12	Tadzhik Academy of Science.
July 13	Departure for Vakhsh Valley. Visit to Kuibyshev state farm, Stalinabad Oblast.
July 14	Visit to Experiment Station of the Institute of Soil Science of the Academy of Sciences of Tadzhik S.S.R. Return to Stalinabad.
July 15	Stalinabad Polytechnic Institute. Institute of Soil Science. Tadzhik Ministry of Agriculture.
July 16	Departure for Tashkent, Uzbek S.S.R. Middle Asian Scientific Research Institute on Mechanization and Electrification of Irrigated Agriculture.
July 17	Travel to Golodnaya Steppe. Visit to Malek state farm, Tashkent Oblast.
July 18	Academy of Agricultural Sciences, Uzbek S.S.R. Scientific Research Institute of Horticulture, Viticulture, and Winemaking.
July 19	Middle Asian Scientific Research Institute of Irrigation. Institute of Soil Science of Uzbek Academy of Agricultural Sciences.
July 20	Travel to Golodnaya Steppe. Visit to Lenin collective farm, Tashkent Oblast.
July 21	Departure for Moscow.
July 22	All-Union Institute of Water Purification, "Vodgeo."
July 23	Institute of Plant Physiology at Timiryazev Agricultural Academy.
July 25	Conference with officials at the U.S.S.R. Ministry of Agriculture.
July 26	Departure for Stalingrad.
July 27	Stalingrad Agricultural Institute. All-Union Institute of Agro-Forestry Amelioration.
July 28	Return to Moscow.
July 29	Departure from the U.S.S.R.

Field Observations and Practices

As shown by the accompanying map, the principal irrigated areas in the U.S.S.R. are in the southern Republics. Soil salinity is a major problem in the Kura-Araks lowlands of the Azerbaijan S.S.R., throughout the Turkmen S.S.R., in the Vakhsh Valley of the Tadzhik S.S.R., and on the Golodnaya Steppe, which occupies parts of the Tadzhikistan, Uzbekistan, and Kirgizia Republics. In addition, there are large areas of salt-affected (Solonetz) soils under dryfarming systems in the vicinity of Stalingrad.

General Description of Areas Visited

The dominant physiographic feature of the Soviet Union is the level or rolling plains that occupy extensive portions of the country. In overall appearance, the U.S.S.R. resembles an enormous amphitheater, with mountain ranges on the southern, eastern, and northeastern borders, and plains in the western, central, and northern areas. The Ural Mountains, which mark the boundary between Europe and Asia in the Soviet Union, separate the European plains from the Asiatic plains. Approximately half of the U.S.S.R. is at an elevation of less than 200 meters, with the rest mainly at elevations below 2,000 meters. About 5 percent of the country is above 2,000 meters, principally in the Pamir and Tien Shan Mountain ranges in central Asia.

The Kura-Araks lowlands in the Azerbaijan S.S.R. are the alluvial plains of the Kura and Araks Rivers. These lowlands, as well as the plains of central Asia in the Turkmenia, Tadzhikistan, Uzbekistan, and Kirgizia Republics, are part of the Turan lowlands, where the climate is arid and the elevations are generally less than 200 meters above sea level. The Turan lowlands were covered by a sea in Tertiary time and are now marked by large depressions, some of them below sea level, into which the rivers of central Asia drain. Salt deposits are widespread in those lowlands.

Central Asia is bordered by high mountains on the south and east. On the north and west, it gradually merges into the semidesert and prairie regions of Siberia and European Russia, with no marked topographic barriers between them. There are two large deserts in central Asia called the Kara-Kum (black sands) and Kyzyl-Kum (red sands). The Kara-Kum Desert is in the Turkmen S.S.R., whereas the Kyzyl-Kum Desert is in the Uzbekistan and Kazakhistan Republics.

Three rivers—the Amu Darya (with its tributary, the Vakhsh River), the Syr Darya, and the Murgab—supply water for the areas in central Asia that we visited. The Murgab River rises in the Kopet Dagh Mountains and ends in the depressions and sands of the Kara-Kum Desert. The Amu Darya, flowing from the Pamir and Hindu Kush Mountains, and the Syr Darya, from the Tien Shan Mountains, empty into the Aral Sea. Several centuries ago, the Amu Darya flowed into the Caspian Sea, and the old channel was once proposed for use as an irrigation canal to open large parts of the Trans-Caspian Desert to colonization and cultivation. This project (Bolshoy Canal) was started under Stalin, but was abandoned after his death as being too expensive to build. Instead, the Kara-Kum Canal, taking water from the Amu Darya near the eastern edge of the Turkmen S.S.R., was initiated. The canal has been completed as far as Mary, a distance of about 400 km., and construction is underway on the section to Tedzhen, another 140 km. Ultimately, the Kara-Kum Canal is to be extended to the Caspian Sea by way of Ashkhabad, near the Iranian border on the south.

After the sea receded from the Turan lowland, large glacial rivers that are now extinct are believed to have deposited much of the sand that occurs in the Kara-Kum and Kyzyl-Kum Deserts. Subsequently, wind action caused the formation of the sand dunes that characterize the present deserts.

In the eastern part of the Kara-Kum Desert and on the Golodnaya Steppe, the soils are said to be of loessial origin. The term "loess," in this instance, does not appear to refer only to deposits of aeolian material but also includes alluvium brought down by the rivers. The Russians also speak of "diluvium" (flood sediments) as contributing to the soil parent material. Consequently, it seems that loess includes aeolian and alluvial deposits, and topographic and soil con-

ditions appear to support the hypothesis that the soils are derived from both types of sediments in this area.

The natural vegetation of the Kura-Araks lowlands is xerophytic and is typified by camelthorn (*Alhagi pseudoalhagi*), locally known as "Kaluchka." When camelthorn grows well, it indicates a low level of soil salinity; when it is stunted, it indicates a medium level of salinity. Russian-thistle (*Salsola dendroides*), *S. verrucosae*, and *Petrosimonia brachiata* occur and tolerate a high level of soil salinity. Bermudagrass (*Cynodon dactylon*) is the most common grass, and it, together with bindweed (*Convolvulus arvensis*), constitutes a serious weed problem.

At the Mugan Experimental Amelioration Station, a poplar (*Populus pyrimidalica*), similar to our Lombardy poplar, is used for shade and for windbreaks. Among the broad-based poplars are *P. hybrida* and *P. alba*. Russian-olive, ash, and elm trees are also used in windbreaks. Open drains are characterized by the presence of *Fragmites communis*, a tall reedgrass that grows along the drains.

The vegetation of central Asia is quite similar to that of the southwestern United States, but some species occur that are absent here or are not common. Among the widespread shrubs, forbs, and grasses are *Alhagi pseudoalhagi*, *A. persarum*, *A. camelorum* (camelthorn); *Petrosimonia brachiata*, a forb indicative of high salinity; *Salsola gemmascens*, *S. crassa*, *S. dendroides*, *S. rigida*, *S. verrucosae* (Russian-thistle and saltworts); *Atriplex* spp. (shadscale); *Glycyrrhiza glabra* (licorice), an indicator of low salinity; *Carex physodes* (sedge); *Suaeda* spp. (saltbush), found on saline soils and common on Takyrs; *Tamarix* spp. (tamarisk), found in wet and salty areas; *Aeluropus littoralis*, a grass indicative of saline conditions; and *Agropyron crestatum* (crested wheatgrass).

The climate of the Kura-Araks lowlands is arid and semiarid, with precipitation generally decreasing from west to east. Rainfall at Baku averages 25 to 30 cm. per year but drops to about 20 cm. in some parts of the lowlands. Winters are rather mild, and the summers are hot.

Precipitation in central Asia varies with the elevation and with the location relative to mountain barriers. In the Turan lowlands, the precipitation ranges from 10 cm. annually in the Kara-Kum Desert to 35 cm. at Tashkent. Summer is the driest time of the year. In the Vakhsh Valley, the average annual precipitation is a little less than 25 cm., whereas in the hilly dryfarming area between the Vakhsh Valley and Stalinabad it increases to 35 to 40 cm.

Summers are hot and winters are cold in the Turan lowlands, whereas winters are mild in the Vakhsh Valley because of the protection from the cold Arctic winds that is afforded by the mountains on the north and northwest. The growing season in the Vakhsh Valley is 280 days, but becomes less to the north.

Kura-Araks Lowlands

The Kura-Araks lowlands are located between the Greater Caucasus and the Lesser Caucasus Mountains southwest of Baku. The Kura River starts in the high mountains to the west, joins the Araks River in the central part of the lowlands, then empties into the Caspian Sea on the east. The Araks River has its source in Turkey and forms part of the international boundary between the U.S.S.R. and Turkey and Iran before turning north to join the Kura River. Sediments of the Kura River are brown, but those of the Araks are red, reflecting the difference in soils in the areas through which they flow. In the watersheds on the west and north, Chestnut, Brown, and Gray soils predominate, whereas Red and Yellow Podzolic or Lateritic soils are found in the southern watersheds.

These lowlands were once covered by the Caspian Sea, which later retreated, and much of the valley is below sea level. The level of the Caspian Sea is said to have dropped 2 meters between 1940 and 1960.

The soils are recent alluvium, stratified, with little or no profile development, and are called Sierozems. Surface soils on the Mugan Experimental Amelioration Station are of medium to fine texture, are calcareous to the surface, and contain gypsum at depths of 20 to 30 cm.

The Kura-Araks lowlands consist of five steppes: Karabakh, Mil', Solyany, Shirvan', and Mugan'. The word "steppe," as used in the Soviet Union, refers to any extensive level-to-undulating area of grass or shrubs. Ground water is said to be near the surface virtually everywhere; it is usually more salty the nearer it comes to the surface. The soils are productive when the salt content is low, but salinity is an ever-present problem. A soil survey, which we did not see, has been made of the lowlands, and the extent and severity of the salinity problems have been mapped. Soil salinity is believed to have increased since irrigation was initiated here, probably caused by the rising of the water table.

An especially serious drainage problem exists on the Shirvan' Steppe where soil permeability is restricted. On the worst soil, we were told, 80 percent of the soil separates were less than 0.01 mm. in diameter, which means that the soil is composed mainly of fine silt and clay. The Azerbaijani believe that, if they can learn how to reclaim the intractable soils at the experimental station on the Shirvan' Steppe, they will be able to reclaim the entire steppe.

Chloride type of salinity is the most common in the Kura-Araks lowlands, but sulfates are dominant on the Shirvan' Steppe, and sodium carbonate is found in the soils of the Karabakh Steppe. Although the statement was made (emphatically) that the exchangeable-sodium-percentage in lowlands soils never exceeds 10, either before or after reclamation, gypsum is used as an aid to reclamation of the soils of the Karabakh Steppe. The solubility of gypsum in the presence of sodium carbonate is said to be so low that it is not so effective as it should be in soil reclamation. An interesting sidelight to the management of Karabakh soils was the disclosure that gypsum is applied simultaneously with anhydrous ammonia in order to acidify the soil in the vicinity of the ammonia injection. Part of the ammonia reacts with gypsum to form ammonium sulfate, and the remaining ammonia is converted to nitric acid, which reacts with lime to form calcium nitrate.

Three soil zones, with respect to salinity and water table, are recognized in the lowlands, and reclamation procedures vary with the kind of problem. The soil zones are (1) high water table, low salinity; (2) high water table, high salinity; and (3) variable soils of alluvial fans.

The guiding principle in reclamation is to decrease the salinity of the surface one-meter of soil as rapidly as possible, and then try to keep that depth of soil sufficiently salt-free to permit crops to be grown. No general procedure for reclaiming all soils is attempted; each soil is considered to be a special case, we were told.

Turkmen S.S.R.

The soils of the desert regions in this republic are classed as Sierozems, with subgroups for sand dunes, Solonchaks, and Takyrs. Soil maps for overall planning purposes, which we did not see, are made at a scale of 1:500,000 by the Soil Institute.

Soils are usually calcareous to the surface, frequently saline, of medium to fine texture, and deep. Gravel is found at a depth of about 230 meters. Medium textures, fine sandy loam to silt loam, predominate in the surface soils of the irrigated sections we visited except in the Takyrs, where textures are finer. Drainage of the irrigated lands is sometimes difficult, because the water table rises under irrigation. We saw some fields in the vicinity of Mary that had been abandoned because of high salinity. Canal losses are 40 to 60 percent of the inflow in some instances and undoubtedly contribute materially to the ground-water problem. Although a member of the Turkmen Institute of Geology said that drainage was difficult because of low soil permeability, we saw no standing water near big canals that was so common in the Kura-Araks lowlands.

Takyr soils occur in large and small depressions, principally in the eastern part of the Turkmen S.S.R. (fig. 3). The depressions are closed basins, called bistochny, and are similar to the playas of the southwestern United States. In one pit dug in a Takyr at the Getchi Gran Takyr Experimental Field, the soil texture to a depth of 110 cm. was fine sandy loam and very fine sandy loam. Below 110 cm. the texture was silty clay loam. The structure was medium blocky in the sandy loam and strong blocky in the silty clay loam. Salt incrustations occurred at the 20 to 40 cm. depth on the face of the pit. The soil surface was hard, and vegetation was sparse or entirely absent. These soils are called Solonchaks, even though they gave every evidence of being sodium-affected, and gypsum is being used to reclaim them. Stands of corn and cotton on the Getchi Gran Takyr Experimental Field were spotty, and growth was poor. Takyrs of a finer texture and completely barren of vegetation are said to occur in other parts of the Turkmen S.S.R.

Vakhsh Valley

The Vakhsh Valley, in the southern part of the Tadzhik S.S.R., has been intensively developed for irrigation since the end of World War II. The valley occupies the flood plain of the Vakhsh River, and much of it was marsh land before a drainage system was installed. The topography is moderately undulating.

Soils are recent alluvium, stratified, deep, generally of medium texture, and permeable. They are called Sierozems, with subgroups for salty

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FIGURE 3.—Poor growth of alfalfa on Takyr soil near Mary.

Sierozems and Solonchaks. The term "Sierozem" is said to have been introduced by Neustrayev while he was working in the Tadzhik S.S.R. Salinity is the major soil problem.

Observed surface soil textures ranged from fine sandy loam to silty clay loam. Subsoil stratification appeared to consist largely of the same textures, although we saw a small lens of coarse sand in one pit. Even though soil permeability appeared to be good, iron mottling was observed in the subsoil of a pit dug in the low part of a field. Since the textures here were fine sandy loam and silt loam, with no evidence of a high water table, it seemed likely that the iron mottling resulted from heavy irrigation rather than from low soil permeability.

At the reclamation experiment station of the Tadzhik Soil Science Institute in the Vakhsh Valley, soils were of medium texture, permeable, and underlain by gravel at about 8 meters. A dense, impermeable stratum occurs at about 48 meters below the surface. The soils at the station contain approximately 20 percent of calcium carbonate and gypsum at a depth of 30 to 60 cm.

One of the major problems faced in the Vakhsh Valley is disposal of the heavy sediment load carried by the irrigation water. Not only does deposition of the sediment necessitate frequent releveling of fields, but also the sediment is said to be infertile. The obvious difficulty the farms have in obtaining a good field-leveling job initially is compounded by the uneven deposition of sediment after every irrigation.

Golodnaya Steppe

The Golodnaya (Hunger) Steppe is described as a loess piedmont plain. It is level as far as the eye can see. The total area of the Golodnaya Steppe is about 1 million hectares, of which 200,000 to 220,000 hectares are irrigated at present. It is hoped that between 600,000 and 700,000 hectares will be under irrigation at the end of the present 7-year plan that ends in 1965. The principal source of water is the Syr Darya, which furnishes irrigation water the year round.

Soils here are Sierozems, of medium to fine texture (very fine sandy loam to silty clay loam) in the surface, deep, permeable, calcareous, and with little or no profile development in most cases. The soils contain between 16 and 22 percent of calcium carbonate in the top 20 cm. Although they are called loessial soils, they are described as being of alluvial and diluvial origin. On the Malek state farm, in the center of the irrigated region, the soils are underlain by sand at 12 meters and by sand and gravel at 16 meters. Wells drilled in this vicinity have struck water at 90 meters, which rose under artesian pressure to 2 meters from the surface. The water table is said to have occurred at about 6 meters prior to irrigation but is now within 2 meters of the surface. Seepage losses from canals contribute materially to the rise of the water table.

Salinity is a widespread problem on the Golodnaya Steppe, and periodic leaching of the soils is a regular practice, beginning with the first preparation of the land for cultivation. We were told at Tashkent that 80 to 90 percent of the land scheduled to be broken out for irrigation in the next several years is affected with salt. Most of the soils of the steppe were Solonchaks, or "slight" Solonchaks, before irrigation was begun. "Slight" Solonchaks are soils in which excess salts occur in the subsoil, but the surface soil is nonsaline.

No Solonetz soils are recognized in the Uzbek S.S.R. We were told that thus far gypsum has not been used in the reclamation of the soils in this Republic. A member of the Uzbek Soil Science Institute did tell us that there are two areas in the Golodnaya Steppe where the soils, at a depth of 40 to 60 cm., contain as much as 43 percent exchangeable sodium and are low in salt. Reclamation of these soils is accomplished in 3 years by growing alfalfa under irrigation.

Stalingrad Area

Stalingrad is situated on the west bank of the Volga River, in rolling country cut by deep gullies, overlooking the Volga delta, which is several miles wide at this point. This is a dryfarming area, with an average annual precipitation of 25 to 35 cm., of which 35 to 40 percent comes in winter. The main farming system is wheat–fallow; the fallow period permits an estimated 4 to 10 cm. of water to be stored in the soil for use by the following wheat crop.

Soils in the vicinity of Stalingrad include typical Chernozem, light Chernozem, dark Chestnut, typical Chestnut, light Chestnut, and recent alluvium of the Volga delta. Solonetz and Solonetz-like soils occur extensively in the Chestnut zone, particularly among the light Chestnut soils (fig. 4). In these areas, Solonetz soils occur in spots, generally of 5 to 50 square meters in size, and occupy from about 5 to 75 percent of the fields that are delineated as Solonetz-affected. We were told at the All-Union Scientific Research Institute of Fertilizers and Agricultural Soil Science in Moscow that there are about 40 million hectares of Solonetz soils and 90 million hectares of Solonetz-like soils in the Soviet Union. By far the majority of the Solonetz-affected soils occur in the vicinity of Stalingrad. Management of these soils constitutes a problem upon which considerable effort is being expended.

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FIGURE 4.—Profile of Solonetz soil near Stalingrad.

The length of the Kara-Kum Canal will be 1,500 km. when completed. At present, it serves 400,000 hectares of land. We were told that it will serve 1 million hectares of land by 1980. At the point of diversion, the flow is 150 cubic meters per second, dropping to 60 to 70 cubic meters per second near Mary, owing to pumping for irrigation, seepage, and evaporation losses. Water is usually pumped from the canal by stationary diesel power plants or by belt-driven centrifugal pumps from tractor-powered takeoffs (fig. 5). Where canal elevation permits, water is removed through siphons or by gravity, but more often it is pumped.

No canal lining is used, and seepage losses are estimated at 40 to 45 percent. During a 2-hour boat ride on the canal, visibility was almost obscured in some places because wind erosion appeared to be a serious problem. Draglines in operation at several points along the canal were modern, and capable of "walking" when moves were necessary. At Mary, irrigated land served by the Murgab River will have a more dependable and adequate water supply when augmented by Kara-Kum Canal water.

In July, the Vakhsh Canal in the Vakhsh Valley of Tadzhik S.S.R. was carrying considerable amounts of silt in the water at flow rates of 160 cubic meters per second. A part of this stream is discharged back into the Vakhsh River to generate power. We were informed that the Vakhsh River normally carries 0.25 and 1.00 gram of silt per liter in winter and summer, respectively.

Irrigation

Conveyance and Distribution of Water

Most of the canal systems observed in the various Republics visited were quite similar to those in irrigated projects of the United States. Very few were lined. Where linings were observed, as was the case near Ashkhabad, Turkmen S.S.R., concrete was used.

The Kara-Kum Canal was one of the most impressive irrigation structures observed during the entire trip. This canal starts at the Amu Darya in the vicinity of Kerki, flows west to Mary, a distance of 410 km., crosses the Murgab River near Mary, and is scheduled to be extended, eventually, to the Caspian Sea via Tedzhen and Ashkhabad. The section between Mary and Tedzhen, a distance of 140 km., is now under construction. The canal is about one-third the size of the All-American Canal (United States), or about the same size as the Friant-Kern Canal in the central valley of California.

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FIGURE 5.—Pumping irrigation water from the Kara-Kum Canal.

Although most of the farm distribution systems are unlined open ditches, there are new developments in the Golodnaya Steppe. We were told that underground pipe systems are being used to deliver water to farm units, with the claim of a fourfold increase in labor productivity; also, that the irrigation pipe being installed is 40 to 70 cm. in diameter and 4 meters long, and that about 35 km. of the pipe have already been installed.

Seepage losses from canals and farm laterals was a problem that was a concern to some Soviet engineers, and some research work was contemplated. In Turkmen S.S.R., we were told that plastic films were being evaluated to determine effectiveness in reducing seepage losses. Near the Mugan Experiment Station, about 200 km. south and west of Baku in Azerbaijan S.S.R., a major effort is being made to develop various methods to compact canal bottoms and sides after construction. Five types of compacting equipment were seen and demonstrated.

A "drop weight" machine is utilized to pack the bottom of the canal (fig. 6). Only clay and loamy soils are compacted. Experiments have shown that compacted conditions remain unchanged for a period of 2½ years. Pronounced packing occurs in the top meter of soil. An indication of the force exerted on the soil was apparent from vibration of the earth several hundred feet away when the heavy weight was dropped. The weight, adapted to steam shovel equipment, was dropped several times in each position.

"Vibrating foot" equipment is used to pack the sides of canals. The "foot," supported on a derrick, is movable along a supporting boom. A large-capacity air compressor energizes the vibrating foot. After several passes in one position, the equipment is moved the width of the foot and the process repeated.

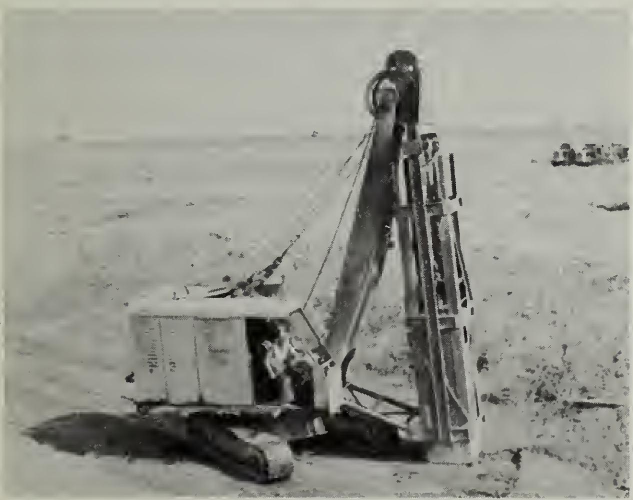

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Figure 6.—Experimental "drop weight" equipment for compacting canal bottoms; near Baku.

Another method used to compact the sloping sides of canals involves a heavy concrete roller. The roller, attached to dragline equipment, is raised about 2 meters and then dropped, beginning at the bottom of the slope. The operator then positions the roller nearer the machine for the next drop, which overlaps the previous compacted area. When the top of the canal bank is reached, the equipment is moved the width of the roller and the process is repeated.

A "rocker-arm" type of packer is in the experimental stage and appeared to be less effective than equipment described above. This equipment permits packing of soil from a position outside of the canal bank or levee. Cables, exposed pulleys, and cable drums appeared hazardous to the operator.

A packer used for farm laterals forms a trapezoidal-shaped ditch. The roller is split in the center and provides for progressively wider adjustments between packer halves and, thus, greater compressive force can be brought to bear on the sides of the ditch being consolidated.

The compaction equipment described was said to be employed in the Azerbaijan Republic and apparently to a limited degree in the Uzbekistan Republic. The delegation felt, however, that such equipment would find little use in the United States, primarily because it is too time-consuming, and also because of equally effective and less costly methods available to contractors. Fast-moving heavy-packing equipment to construct canals and to place clay linings and other materials where seepage losses are great are preferred procedures.

Water measurement and structures to control water were evident in all Republics visited (fig. 7). The Cippoletti weir was universally used to measure water in open channels. Smaller models of the same weir were observed in measuring tile effluent from closed drainage systems and in open collector drains on the Mugan Experimental Amelioration Station in Azerbaijan S.S.R. and at the Institute of Soil Science Experiment Station in the Vakhsh Valley, Tadzhik S.S.R.

At the Middle Asian Scientific Research Institute, a model of a so-called turbine-type water-measuring device was displayed. The principle of operation was similar in certain aspects to the Sparling meter manufactured in the United States. However, the meter appeared to be part of an irrigation structure used to control water levels in farm laterals. A portion of the stream is bypassed through a pipe section beneath the overflow in which is placed an impeller connected to a meter. The meter is apparently calibrated

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FIGURE 7.—Control structure on canal in Vakhsh Valley.

to measure total discharge of the structure. This water-measurement device lacks portability embodied in more recent water-measurements developments in the United States.

At the same institute, work was in progress on devices for automatic control of upstream or downstream water levels in open channels. From all appearances, these devices were nearly the same as those developed in the Dauphinois Hydraulic Laboratory at Grenoble, France, and manufactured under patent controls by the Thompson Pipe & Steel Co., Denver, Colo., U.S.A.

According to S. R. Offengenden,[2] water-measuring devices in general use in the Soviet Union include trapezoidal Cippoletti weirs, weirs constructed by A. I. Ivanov, engineer, metering nozzles designed by the Middle Asian Scientific and Research Institute of Irrigation (SANIIRI), tubal metering regulators, dynamic discharge recorders and rotor runoff counters designed by SANIIRI, semi-automatic meters and automatic metering devices to measure runoff designed by K. S. Glubshev, partial metering regulators designed by the All-Union Scientific and Research Institute of Hydrotechnics and Amelioration (VNIIGIM), etc. Calibrating of orifices for hydraulic structures is also widely used.

Diversion structures with steel gates were observed in all Republics and are comparable to installations in this country. Most of them were concrete, but some were made of wood. Water-control gates in the larger diversion and storage dams appeared to be more modern than some observed on the collective and state farms visited.

Irrigation Systems and Design

Furrow-irrigation systems in Russia are designed with an application efficiency of 85 percent. It is obligatory in field practice that this degree of efficiency be attained. Such requirements would necessitate very little wastage of applied water as runoff from the lower end of the field. In all our travel, we saw very little

[2] OFFENGENDEN, S. R. PLANNING OF WATER UTILIZATION IN THE U.S.S.R. U.S.S.R. Min. Agr., All-Union State Design and Res. Inst. for Land and Water Devlpmt., 48 pp. 1960. Moscow. [In English.]

water being wasted in this manner, but considerable labor was required to get the job done. There is also the question of how adequately the lower end of the field was irrigated, particularly on steeper sloping land. Some fields were observed where applied water did not reach the end of the rows. In other instances, check dams in the furrows were required to get water over high spots. With such deficiencies in water management, the 85 percent application efficiency claimed appears high. Irrigation systems in the United States are more often designed with 50 to 65 percent application efficiency, simply because irrigation farmers in general are willing to sacrifice low-cost water for high-cost labor requirements.

A publication by S. R. Offengenden,[3] describes how irrigation systems are being designed in Russia today. Data required for determining limits of water delivered to a farm unit and the plan of water within an irrigation scheme include:

(a) Irrigated areas under crops and orchards commanded by a separate structure or a canal and saline lands meant for washing out within each farm, (b) consumptive use of crops, (c) designed regime of an irrigation source, (d) efficiency factors of canals, and (e) an irrigation map or a sketch of a system.

Further details regarding calculations of efficiency factors of irrigation schemes, water-distribution balance, and water rotation are also presented in the publication.

Furrow irrigation for row-crop production was the most common irrigation method used. The collective farm Zhdanov near Chardzhou, Chardzhou Oblast, Turkmen S.S.R., was the only place observed where spiles were being used to control the flow of water in furrows. Irrigation on this farm was the best example of good water control and management observed in Turkmen S.S.R. Length of runs ranged from 300 to 600 feet on what appeared to be a sandy loam ideally suited for irrigation.

An interesting development in the use of lay-flat canvas tubing was demonstrated on the Malek state farm near Tashkent, Uzbek S.S.R. Openings in the tubing were provided by attaching smaller canvas tubes to outlets to reduce erosion. The director of the farm indicated they were not entirely satisfied with this method for distributing water to furrows and that further tests were being made.

Cotton rows are ordinarily spaced 45 to 60 cm. apart in the Soviet Union, but at Malek we saw rows spaced 1 meter apart. Meter-wide rows allow for larger furrows and more nearly correspond to cultural practice in the United States. The larger beds facilitate better water distribution despite minor variations in furrow gradient that may exist throughout the length of run. When commenting on this point later at the Institute of Soil Science of Uzbek Academy of Agricultural Sciences in Tashkent, a statement was made to the effect that the director of this farm was "ultra-modern." In general, the delegation was impressed with the good irrigation practices being utilized on this particular field of cotton.

A less attractive method of furrow irrigation was observed on the collective farm Leninism, Mary Oblast, near Mary, Turkmen S.S.R. Here water was taken from a farm ditch that paralleled the cotton rows. About every 50 meters a small ditch formed by hand and perpendicular to the furrows connected with a larger centrally located ditch (fig. 8). It was necessary to reform the ditches that crossed the furrows each time the field was cultivated. Labor requirement to handle water in this manner appeared great, but undoubtedly a reasonably high irrigation application efficiency was possible because of extremely short runs in each isolated block.

Generally speaking, length of runs appeared to be reasonable for efficient application of water. At the Middle Asian Scientific Research Institute of Irrigation in Tashkent, studies are being made on row lengths of 300 to 400 meters where soil conditions permit, in order to reduce labor requirements. However, the usual length of run ranges from 70 to 200 meters on coarse- to medium-textured soils.

Basin irrigation was practiced in the production of rice and on some orchards near Stalingrad. The techniques employed were comparable to those used in the United States.

Sprinkler irrigation in Russia receives limited use. The "big gun" type of nozzle that has had very little success in the United States is also being tested in Russia. One model was on display at the Middle Asian Scientific Research Institute on Mechanization and Electrification of Irrigated Lands in Yangi-Yul near Tashkent, Uzbek S.S.R.

Two giant "boom-type" sprinkler systems were seen in operation, one on the Mugan Experimental Amelioration Station in Azerbaijan S.S.R., and the other on the Malek state farm in Uzbek S.S.R. (fig. 9). We were told that about 200 of these spray machines were in operation in the southern and central Asian Soviet Republics. Water from the farm lateral is measured over a Cippoletti weir into a supply ditch centrally located in the field. A pump and scoop attached to a track tractor draws water from the ditch and pressurizes the water in 52 nozzles placed along the boom estimated to be 120 meters long. Water is delivered at the rate of 90 to 100 liters per second and covers 10 hectares in 24 hours. The application rate appeared to be large, and wind was adversely affecting the distribution pattern during the demonstration.

[3] See footnote 2.

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FIGURE 8.—Irrigation of cotton with laterals perpendicular to rows.

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FIGURE 9.—Experimental "moving boom-type" sprinkler pumps water from field ditch.

The delegation was told that the sprinkler equipment gave a 7-centner per hectare yield increase of seed cotton while using 45 percent less water over fields that were supplied water from furrow irrigation. Similar developments of sprinkler equipment in the United States have had limited success. Generally, where soil and topography are suitable, surface irrigation methods are much preferred in the United States.

Land Preparation for Irrigation

One of the greatest deficiencies insofar as preparation of land for irrigation in the U.S.S.R. was the complete absence of landplanes or farm-type levelers and the two-way plows that are considered a necessary and integral part of well-managed irrigation farms in the United States.

Large tractors and five- or six-bottom plows are used on irrigated farms. Use of such equip-

ment does not maintain the fields in a leveled condition for uniform application, distribution, and efficient use of water (fig. 10). More important is the lack of good land levelers that can eliminate relatively small but troublesome variations in elevation of the soil surface. One type of land leveler used on the collective farm Zhdanov is more like a float than a land leveler and could not be expected to remove high spots much larger than the equipment itself. We were informed that tractor-drawn road graders are often used for major leveling on some farms each year, but are used only once every 9 years on other farms.

The inadequacy of leveling operations was evident from poor stands of cotton obtained in most irrigated areas visited (fig. 11). Bare areas were not entirely associated with high spots receiving inadequate water for germination, however. Incomplete leaching of soluble salts and high water tables midway between drains undoubtedly were other causative factors. However, it appeared that much of the problem of poor stands could be associated with poor leveling operations that could be easily solved with adequate plowing and leveling equipment. That the scientists and engineers in Russia are fully cognizant of this deficiency was evident by the statement made at the final conference held in Moscow following the field tour, to the effect, "Come back in 2 years and you will find a land leveler on every farm."

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FIGURE 10.—Land leveler used on collective farm near Chardzhou.

Irrigation Management

In general, it appeared that most crops, particularly cotton, were being irrigated reasonably well. With a few exceptions, irrigation schedules based primarily upon experience were practiced. The quality of the ground water, soil texture and depth, and diversity of climate in a given area were recognized as important factors

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FIGURE 11.—Uneven stand of cotton on poorly leveled land.

in determining water requirements and irrigation schedules. The number of irrigations applied to cotton ranged from 2 to 12, but more often 6 or 7 seemed to be the usual practice. The number of irrigations was reduced to 1 or 2 where water tables were within reach of plant roots.

Cotton was irrigated in some instances when plants showed signs of wilting. In one place, color change or darkening of foliage with the associated "flush" of blossoms that appear over the field was used as a criteria for irrigation. Experiments in the United States have indicated that under certain conditions, similar criteria can be used successfully. In most instances in the U.S.S.R., however, the farmer's judgment and water delivery schedules dictate the schedule followed. In this respect, practices in Russia and in the United States have much in common.

Irrigation requirements of cotton are expressed in cubic meters per hectare. Figures reported for irrigation water ranged from 2,400 to 8,000 cubic meters per hectare or about 24 to 80 cm. of water. These figures presumably include application field losses. The wide variation in values is primarily due to the presence or absence of a usable water table.

Regarding evapotranspiration or consumptive use of water by crops and associated procedures for measurement, there appeared to be little work on this subject. The Institute of Soil Science in Stalinabad was one of the few places where such studies had been conducted. From all indications, conventional gravimetric soil sampling procedures to measure soil moisture loss for given periods of crop growth were used in these studies. More often, the response to questions regarding evapotranspiration of crops was answered in terms of *duty of water* and the amount of water in cubic meters per hectare required to grow a given crop.

Off-season irrigation is practiced in the region east of the Volga River near Stalingrad with reportedly good success. The usual procedure is to irrigate during the winter months to a wetted depth of 2 meters or more, with no further irrigation. This irrigation practice appears particularly well adapted to wheat and potato production where rainfall ranges from 30 to 40 cm. annually.

Summary of Impressions Relating to Irrigation

One is impressed by the irrigation potential in the southern Soviet Socialist Republics visited, from the standpoint of both irrigation water supply and irrigable soils. Water quality is good and most soils observed are well adapted to irrigation. Reclamation does not appear difficult, in most instances, and full crop production is usually attained within 2 to 5 years.

In general, irrigation practices appeared fair, but could be improved with more modern machinery, as two-way plows and land levelers. Better land preparation would provide for more efficient application, distribution, and use of irrigation water, and at the same time would reduce labor requirements. Increased production also should be possible with better stands on presently nonproductive field areas.

More use could be made of siphons and canvas dams for better on-farm water control, and with less labor requirement. With the exception of lay-flat tubing and spiles, such facilities were noticeably absent.

Narrow-row spacings of crops grown on relatively level land, particularly cotton, appear incompatible with the high application efficiencies claimed. The high application efficiency, in view of obligatory demands that little or no runoff occur from inadequately leveled fields, raises a question of how uniformly water is applied. Larger furrows and cutback procedures to reduce furrow flow would seem to offer greater possibilities for high application and distribution efficiencies.

Leaching

Leaching Principles and Concepts

The principle of leaching, i.e., that excess salts are removed from soils by passage of water through the soil, is held by the Soviet scientists and leaders to be the most effective means for reclaiming saline soils (fig. 12). They recognize that drainage is essential and that provision for drainage must precede leaching.

Our group wished to know if they had anything similar to our "leaching requirement" concept, which pertains to salinity control and is defined as the fraction of the irrigation water applied to the soil that must be leached beyond the root zone as drainage water, in order to maintain a salt balance and a favorable salinity level in the root zone of the soil. There was no indication of an equation or definitive statement of this concept among the Russian scientists, but there was a general awareness of the need for a given fraction of the irrigation water delivered to an area to be discharged as drainage water (drainage percentage). Values of the drainage percentage that are used in planning and those that actually occur were reported for several areas in Azerbaijan S.S.R. Designs are based on a drainage percentage of from 25 to 35 percent. This includes only drainage waters that

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FIGURE 12.—Reclamation of saline land by leaching in the Vakhsh Valley.

seep into drains from ground water, since irrigation developments are planned for no surface runoff. Actual drainage percentages of 35 and 65 percent were reported for the Shirvan and Mugan Steppes, respectively.

Leaching Methods

The methods used for leaching in the Soviet Union are essentially the same as those used in the United States and other countries of the world. They are as follows:

(1) Continuous ponding.
(2) Ponding with a rice crop.
(3) Application of excess water during irrigation of a crop.

It is a general practice to install temporary open drains to aid in removal of excess water during periods of leaching. After reclamation, the temporary drains are filled.

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Quantities of Water Used for Leaching

The amounts of water used for leaching vary considerably from one locality to another. The differences were not related so much to the severity of the problem but to the basic philosophy regarding the adequacy of leaching. For example, 40,000 to 50,000 cubic meters of water per hectare (4- to 5-meter depth) are recommended for leaching saline soils at the Mugan Experimental Amelioration Station in Azerbaijan S.S.R. The Soviet philosophy behind this recommendation is to "leach the soil once and for all"—"replace the saline ground waters with fresh water to a great soil depth (6 meters or more) and thus eliminate the need for further leaching."

In the Vakhsh Valley, Tadzhik S.S.R., a general recommendation for reclaiming saline lands is 18,000 cubic meters per hectare (1.8-meter depth). This quantity of water is applied without a crop and is in addition to the rainfall, which is about 30 centimeters per year. When

rice is grown, it is necessary to apply about 25,000 to 30,000 cubic meters per hectare. Part of the water applied is used by the crop and part is lost by evaporation.

On the Golodnaya Steppe the quantity of water used for reclamation is from 10,000 to 12,000 cubic meters per hectare (1.0- to 1.2-meter depth), applied in several increments. This is in addition to rainfall, which is about 25 centimeters per year. Leaching is usually done in the fall or winter months. When rice is grown, the leaching is continuous. With no crop, the leaching is usually intermittent. For example, on Malek state farm, Uzbek S.S.R., the practice is to leach with water to 20 to 25 centimeters in depth from 1 to 3 times during November, December, or January.

Leaching Equation

Academician V. R. Volobuyev of the Azerbaijan Institute of Soil Science and Agrochemistry has proposed a formula for calculating the amount of leaching water required for reclamation of saline soils. The formula is:

$$N = K \log \left(\frac{S_1}{S_2}\right)^{\alpha}$$

where N=cubic meters of water per square meter of surface area; K=a constant (1 when surface area is 1 square meter); S_1=original salinity, in grams per liter; S_2=permissible salinity, in grams per liter; and α=a parameter that depends upon soil texture and the salinity of the leaching water.

Salt Movement in Soils

Soviet scientists, generally, recognize the fact that salts move with water; however, in two instances, arguments were advanced that are contrary to this concept. At the Kostyakov All-Union Institute of Hydrotechnics and Soil Amelioration, the thesis was advanced and studies reported as evidence for the theory that salts move ahead of and accumulate faster than water in soils. The experimental studies were conducted with soil columns in which water moved upward into the soil with evaporation prevented at the surface.

At the Institute of Soil Science at Tashkent, Uzbek S.S.R., the movement of salts by diffusion and in a direction that is opposite to that of water movement was pointed out as a factor in the reclamation of saline soils. A flow rate of 20 centimeters per day was given as a rate at which salts move with the water and 1 centimeter per day as the rate at which salts can move by diffusion counter to the direction of water flow.

Drainage

Drainage practices were observed in the Republics of Azerbaijan, Turkmenia, Tadzhikistan, and Uzbekistan. The drainage works in these Republics are constructed primarily in conjunction with irrigation development for the purpose of discharging both excess waters and excess salts (fig. 13). We did not visit any areas in the Soviet Union where drainage is practiced solely for discharge of excess water, as in the case of swampy or high rainfall areas.

The information on drainage theories and practices reported here was obtained by direct observation in the field and through discussion with scientists and officials at various governmental institutions and with farm officials and leaders.

Among the major questions in the minds of the delegates as we reviewed and observed drainage in the Soviet Union were: What is the extent of the drainage problem? What is the state of development of the science or art of drainage? How effective are their systems in providing drainage and salinity control? What are the principles or concepts that govern drainage design and practice?

Extent of the Problem

We were unable to get statistical data on the areal extent of the drainage problem in the arid regions alone; however, it was determined that drainage development essentially parallels irrigation development. Drainage is generally considered a requisite to successful irrigation, especially where salinity is involved. We were shown a map that outlined the drainage problem areas in the south-central part of the country; from visual inspection the drainage problem areas appeared to coincide essentially with the irrigated areas of the region.

Types of Drainage

In the areas that we visited, open drains (termed collectors) appeared to be used almost exclusively. Open drains are used on the farms as collectors for controlling the water table and as main outlet drains for discharging excess waters from a given area (fig. 14). Experimental installations of tile drains were described in connection with research studies in Azerbaijan S.S.R., and it was reported that tile drains were being used in newly developed lands on the Golodnaya Steppe, but we saw no tile drains on farms anywhere in our travels except on the experimental farm at Mugan, Azerbaijan S.S.R.

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FIGURE 13.—Pumping drainage water into irrigation flume.

Pump drainage from wells was reported as being used on about 10,000 hectares of the Golodnaya Steppe. Some wells are for drainage only, but most of the wells drilled to date (approximately 1,000, varying in depth from 50 to 500 meters) are used for irrigation and domestic purposes. Because operation of the irrigation system is seasonal, domestic water supplies are obtained from wells. Therefore, wells that are strictly drainage wells are those from which the water is too salty for other uses. Sometimes, high-salt well waters are mixed with surface water for irrigation.

Depth and Spacing of Open Drains

The depths of open drains in the four southern Republics visited were observed to range from about 1 to 5 meters and the spacing from about 200 to 3,000 meters. In general, the intermediate farm collectors are spaced from 200 to 350 meters and are from 3 to 4 meters deep. The main collectors (outlet drains) are spaced from 500 to 3,000 meters and are usually 3.5 to 5 meters deep. Only in one location did we see drains less than 2 meters deep. This was near Chardzhou in the Turkmen S.S.R., where an underlying sand, because of its instability, limited drain depth to about 1 to 1.5 meters. Even with this shallow depth, the drain spacing was from 600 to 3,000 meters. This was considered adequate by the local agricultural leaders.

Drainage Outlets

Suitable outlets for drainage waters were noted to be a problem on many of the projects of the southern Republics. Extremely flat lands or perched river beds are the major problems in obtaining drainage outlets. In Azerbaijan S.S.R., long outlet drains are being constructed to discharge drainage waters into the Caspian Sea. To date (1960), more than 3,000 km. of collector drains (mostly outlet drains) are reported to have been completed. These outlet drains extend the total length of the irrigated areas of the Kura-Araks Lowlands, parallel to and on both sides of the Kura River to the Caspian Sea.

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FIGURE 14.—Left, Shallow open drain near Chardzhou: right, deep open drain in Vakhsh Valley.

For the irrigated areas along the Amu Darya (near Chardzhou) and along the Syr Darya (Golodnaya Steppe) long outlet drains paralleling and finally emptying into the rivers are required. These rivers are not as yet regulated; they carry heavy silt loads and consequently have perched beds. Because of this, the annual fluctuation of the water table in the irrigated areas is influenced by the stage of the river.

Construction and Maintenance of Drains

Open drains are dug by dragline. We saw no machines for installing tile drains. The cost of construction for open drains was reported as ranging from 65,000 to 75,000 rubles per kilometer for an average farm drain (approximately 3 to 4 meters deep) and the cost of tile drains 100,000 rubles per kilometer.

High maintenance cost is recognized as a disadvantage of open drains. It is necessary to clean the weed and tule growth from open drains about every 3 years and the cost of maintenance is approximately 1,500 rubles per kilometer per year.

Drain Tile

At the Institute of Hydroengineering and Amelioration of the Ministry of Water Economy located at Baku, we were shown samples of three different kinds of drain tile for which research was being conducted. These tile drains were porous tile. One was a porous concrete tile having a porosity of 45 percent. It was made with rather coarse aggregate and appeared to lack strength. A second tile was similar to the first but coated with asphalt to give it greater durability. The third was a fired-clay tile molded from rodlike extrusions of clay. The individual extrusions, which were about one-half centimeter in diameter, seemed to be dense and of good quality. They were so molded together that the spaces between the extrusions resulted in a porosity of about 65 percent. Of the three samples, the third one appeared to have the greatest possibility for success. The greatest difficulty was obviously the control of the uniformity of spaces or opening between the extrusions.

Drainage Concepts and Theories

In our discussions with scientists, government officials, and farm leaders there were a number of concepts that were more or less universally held as general criteria for drainage practice and design in the irrigated areas of the south-central Republics. Some of the important ones follow:

(1) *Need for drainage for irrigation and reclamation.*—Soviet scientists recognize drainage as an essential part of irrigation agriculture. The reclamation of virgin lands, especially where salinity is a problem, requires provision for drainage. Drainage is usually considered as a first step in the reclamation process and is subsequently required not only to control ground water levels but for salinity control as well.

(2) *Influence of drainage on the irrigation of crops.*—It was pointed out at several of the locations visited that the quantity of water required for irrigation increased considerably where the water table was lowered by deep drainage. For example, on the Malek state farm on the Golodnaya Steppe, Uzbek S.S.R., only one or two irrigations per year were reported as being necessary for cotton where the water table was high, compared to five irrigations per year with deep drainage.

In the area near Chardzhou in Turkmen S.S.R. we were told that the number of irrigations for cotton was reduced from six or seven per year to five or six by maintaining a shallow water table. In this case, it was reported that the water table was controlled at approximately 1 meter to provide water for crop use. However, it was observed that the depth of drains was limited by an unstable sand in the profile at a depth of 1 to 1½ meters. It appeared, therefore, that the depth of water table at this location may have been the result of a physical limitation, rather than one of design. In any event, the fact that the cotton crops seemed to be somewhat better in this area than in some other areas visited indicates that a shallow water table, per se, is not necessarily detrimental, but may be beneficial in supplying water for crop use.

In other areas, such as the Vakhsh Valley, Tadzhik S.S.R., no attempt is made to control water tables for crop use. On the contrary, drainage systems are designed to maintain the water table as deep as possible on the theory that the greater the depth to water table the better.

(3) *Desirable depth of water table dependent on the salt content of the ground water.*—Desirable depths of water table are based on the salt content of the ground water, and this criterion is used in determining depth and spacing of drains. For example, in the Vakhsh Valley, Tadzhik S.S.R., the permissible water table depth is 1½ meters, if the salt content of the ground water is less than 1 or 2 grams per liter. For a salt content of 3 to 5 grams per liter, the depth of water table should be 2.5 meters or deeper.

(4) *Maintenance of quality as well as control of depth of ground water.*—Water is applied to the land not only to leach excess salts below the root zone but also to displace saline ground water and replace it with good quality irrigation water. Ground water studies have been conducted at the Mugan Experimental Amelioration Station, Azerbaijan S.S.R., to show the change in ground water quality as a result of leaching with large quantities of good quality irrigation water. Changes in quality of ground water were reported at a depth of 10 meters as a result of leaching with approximately 5 meters of water.

(5) *Use of temporary drains.*—Temporary drains are constructed to control water table depth and discharge excess water during periods of abnormally high water table. This practice is followed in reclaiming saline soils. We were told that it is common practice to dig drains at one-half the spacing ultimately desired and after the leaching period to fill in every other drain. We observed such drains scheduled for filling at the Mugan Experimental Amelioration Station, Azerbaijan, S.S.R.

Temporary drains are also utilized on farms during periods of high water table. For example, at the Malek state farm, Uzbek S.S.R., we were told that when the water table rises above a depth of 1.6 meters, temporary drains are installed. The logic of this practice is based upon the higher drainage rates required during periods of leaching or when water tables are too high, coupled with the need to minimize the number of open drains to accommodate farming operations. Whether the practice is or is not sound is largely a matter of economics. It would seem that tile drainage would offer a better solution to the problem. However, the present lack of development of tile drainage methods and equipment may account for the former practice being used.

(6) *Design for no surface runoff.*—At several locations, it was pointed out that drainage systems were designed for removal of ground water only. It is planned that there will be no surface waste or runoff from irrigation. It was observed that at least, in some areas, this objective was not being met. For example, in the Vakhsh Valley, Tadzhik S.S.R., where the irrigation water is very silty the waters of many of the drains were also silty, indicating that surface water was being discharged into the drains. In the area near Chardzhou, Turkmen S.S.R., this

same thing was also observed. Moreover, electrical conductivity measurements of drainage waters, which we made while in the area, indicated that drainage waters were being diluted by surface waters.

(7) *Conversion from open drainage to tile drainage.*—The advantages of tile drains, especially for on-the-farm drainage, were discussed at a number of locations, and plans were reported for converting from open drains to tile drains at some future time.

(8) *Use of mole drains in conjunction with open drains.*—At the Kostyakov All-Union Institute of Hydrotechnics and Amelioration a practice was described that utilizes mole drains spaced at shallow depths between deep open drains, the object being to utilize low-cost mole drains and to allow wider spacing of open drains. Experimental trials were reported as being in progress in the Transcaucus region and on the Golodnaya Steppe, but we did not see any mole drains or equipment for installing mole drains anywhere on our trip.

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FIGURE 15.—Tractor with attachment for applying liquid fertilizer to cotton.

Soil and Crop Management

The principal crop grown in the irrigated areas of the Soviet Union is cotton, both medium staple (upland) and long staple. Most of the long staple cotton is grown in the southern part of the Tadzhik S.S.R., in the Vakhsh Valley. Other irrigated field crops include sorghum, alfalfa, corn, small grains, and vegetables. Rice is raised for local consumption in the Azerbaijan and Tadzhikistan Republics.

Fertilizer practices in the irrigated sections are similar to those used in the southwestern United States. The recommended ratio of N, P_2O_5, and K_2O for nonlegumes is 1:1:1 or 1:1:½, but the quantity actually used varies from these ratios, with potassium generally omitted, as far as we could tell. On cotton, the rate of application of fertilizer ranges from 60 to 140 kilograms per hectare for nitrogen and 60 to 170 kilograms per hectare for available P_2O_5. Potassium, when used, was at the rate of 50 kilograms per hectare of K_2O or at one-half the nitrogen rate. Other nonlegumes receive the same or less fertilizer than does cotton. Only phosphorus fertilizer was used on alfalfa at the farms we visited.

Ammonium nitrate is the favorite form of nitrogen fertilizer, but ammonium sulfate is also used widely. Other nitrogen carriers that were said to be available are urea, calcium nitrate, potassium nitrate, sodium nitrate, ammonium chloride, and anhydrous ammonia (fig. 15). Single superphosphate (18 to 20 percent available P_2O_5) was the only phosphorus fertilizer mentioned. Both muriate and sulfate of potash are used. Dried manure, in small amounts, is mixed with the commercial fertilizers to add organic matter to the soil. Caking of fertilizer is a constant problem, and it was common to see fertilizer lumps being crushed in the field before application.

Split applications of nitrogen and phosphorus on cotton are favored. From one-third to one-half of the nitrogen and about one-half of the phosphorus are broadcast and plowed in before seeding. The remainder of the phosphorus is side-dressed in one or two applications later in the season and the nitrogen in one to four applications. At the Malek state farm on the Golodnaya Steppe, aerial application of phosphorus was used, and the sprinkler system at the Mugan Experimental Amelioration Station in Azerbaijan was equipped to make spray applications of fertilizer.

Judging from the appearance of the crop, cotton seemed to be well fertilized. Symptoms of nitrogen deficiency were not common and where yellowing did show, it was usually in low spots in the fields where extra leaching occurred.

Considerable experimental work is being done at several institutes on adaptations of plows to special purposes. Two- and three-level plows have been devised, some without moldboards on the lower plow, in order to stir up the subsoil without changing its position relative to the surface soil. Others, for use on Solonetz soils, have sweeps running about 10 cm. below the single plow. Two-level plows (one level with a moldboard and one without a moldboard) or plow-sweep combinations are used to improve the permeability of Solonchak and Solonetz soils and hasten reclamation without adversely affecting

the salt or exchangeable sodium content of the surface soil (fig. 16).

The Middle Asian Scientific Research Institute on Mechanization and Electrification of Irrigated Agriculture at Tashkent has been testing a two-level plow with a fertilizer attachment that places phosphorus at the bottom of both plow levels. It was claimed that a single split-level phosphorus application gave a 4.5-centner-per-hectare yield increase of seed cotton over the usual practice of one broadcast and two band applications of fertilizer. Since we did not see any of the special plows in operation in fields, it is impossible to say how widely they have been used.

Three practices used widely in the cotton growing areas of the Soviet Union are different from cultural practices used by American farmers. These three practices are narrow-row spacing, checkrow planting, and topping of the plant.

Cotton rows in the Soviet Union are usually from 45 to 60 cm. apart, which is about one-half the row spacing used in the irrigated sections of the United States. The narrow spacing is belived to have two important advantages over wider spacing. First, it brings about higher yields by increasing the number of plants per unit area and, second, it facilitates mechanical harvesting by inducing upward rather than outward growth of the plant. The disadvantage of narrow rows from the standpoint of irrigation is pointed out in the section on irrigation.

Checkrow planting of cotton, a new experience to us, was said to have been initiated in the Tadzhik S.S.R. as a means of facilitating mechanization of tillage practices. As done in the Soviet Union, plant and row spacing is about 50 cm., and the checkrow planting equipment is like that used in the United States for checkrowing corn. Checkrow planting permits cultivation across the rows as well as along them, but cross cultivation makes the maintenance of good irrigation furrows difficult. We could not determine what percentage of the cottonfields were checkrowed, but it was probably not much more than half the fields we saw. Where checkrowing is not done, plant spacing in the row is from 10 to 20 cm.

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FIGURE 16.—Two-level plow for reclaiming Solonetz soils.

Topping cotton was said to be mandatory throughout the U.S.S.R. It consists of manually snapping off the topmost and outermost buds of upland cotton and the topmost buds of long staple cotton when the cotton plant is about 60 centimeters high, generally. Topping cotton is believed to increase yields by 2 to 3 centners per hectare over yields obtained when the cotton plant is allowed to grow to its full height of about 120 centimeters. Topping is usually done between July 25 and August 5.

The theory back of the topping operation is that bolls formed after the topping period probably will not mature anyway and restricting further vegetative growth will enable the plant to devote its energies to filling out and maturing bolls already formed. This theory was popular in the United States several years ago and some topping is still performed in the United States, but tests conducted at the New Mexico Agricultural Experiment Station in 1932 did not show any difference in yield between topped and untopped upland cotton.

Crop rotation on cotton land is recognized as a desirable practice. The recommended rotation calls for 3 years of alfalfa, followed by 6 years of cotton. In practice, cotton is grown continuously (30 years at the Leninism collective farm near Mary) or for more than two-thirds of the time. Modifications of the rotation are recommended on saline soils; for instance, 2 years of alfalfa and 4 years of cotton, or 3 years of alfalfa, 5 years of cotton, and 1 year for releveling the land.

Weeds are a serious problem in the irrigated areas, and the worst weeds there are the same ones that are a nuisance in southwestern United States. Bermudagrass and johnsongrass cover the irrigation canal banks and extend out into the fields. Bindweed shows up regularly. Tractor cultivation is sometimes used to control weeds, but we saw many fields where women were pulling the weeds by hand.

Our data on 1959 cotton yields are sketchy. For single farms, quoted yields ranged from 2.0 to 3.2 metric tons of seed cotton per hectare (about 1.2 to 2.0 United States bales of lint cotton per acre). Tadzhik S.S.R., with an average yield for the entire Republic of 2.8 metric tons per hectare (about 1.8 bales of lint per acre) in 1959, was said to have the highest average yield of all cotton-growing Republics. Nonsaline soils on the Malek state farm were said to yield 4.0 to 5.0 metric tons of seed cotton per hectare (about 2.4 to 3.0 bales of lint per acre). Saline soils on the same farm yielded 0.9 to 1.0 metric ton (about 0.6 bale of lint per acre).

Most phases of horticulture (breeding, growing protection, machinery testing, winemaking, etc.) are being studied at the Scientific Research Institute of Horticulture, Viticulture, and Winemaking near Tashkent, Uzbek S.S.R., or at one of the 11 branch experiment stations associated with the Institute. Research is being conducted on the common fruits, berries, nuts, and subtropical fruits. Recommendations are prepared here for fruit adaptation to different soils, salinity conditions, and climates.

Research on salt tolerance of various species and varieties of fruit is being conducted. Particular mention of Cl toxicity to grapes was made (0.03 percent is toxic). A variety of grapes named Kishmish was said to be very tolerant of salinity and is used as rootstock for other varieties.

For peach production, the land is manured and plowed to a depth of 50 to 60 cm. before the trees are planted. The water table should always be deeper than 3 to 4 meters. The orchards are cultivated twice annually. Deep cultivation (depth, 18 to 20 cm.) is done around the trunk and outside of the drip. The latter deep cultivation is presumed to prune roots and stimulate new adventitious roots. The trees are fertilized with 60 kilograms of nitrogen per hectare in the fall and with 60 additional kilograms in the spring. Phosphorus is applied in the autumn at the rate of 60 kilograms per hectare. No peach mosaic or iron chlorosis was said to occur in this Republic.

Research

Organization of Research Institutes

Research institutes visited by our group in the U.S.S.R. fitted, organizationally, into four categories. Institutes of the first category, such as the Dokuchayev Institute of Soil Science in Moscow, are under the jurisdiction of the U.S.S.R. Academy of Sciences, but cooperate with the U.S.S.R. Ministry of Agriculture, State Planning Committee, and other agencies. All-Union Institutes constitute the second category and are units of U.S.S.R. ministries. They may, or may not, be affiliated with academies of sciences or academies of agricultural sciences. The All-Union Scientific Research Institute of Fertilizers and Agricultural Soil Science is affiliated with the Lenin Academy of Agricultural Sciences, but the All-Union Institute of Agro-Forestry Amelioration is not. Both are units of the U.S.S.R. Ministry of Agriculture. "All-Union" means that the institute has research responsibilities to the entire Soviet Union, not to a Republic alone.

The third category is represented by the Middle Asian Scientific Research Institute of Irrigation at Tashkent. It is a unit of the U.S.S.R. Ministry of Agriculture that confines itself to work in one part of the Soviet Union (the irrigated area).

The fourth category of organization of research institutes is that of a constituent Republic research institute. Here, the institute is under the jurisdiction of a Republic academy of sciences or a Republic academy of agricultural sciences. The Institute of Soil Science at Stalinabad was under the Tadzhik Academy of Sciences, whereas the Institute of Soil Science at Tashkent was under the Uzbek Academy of Agricultural Sciences.

All-Union research institutes are somewhat comparable to divisions of the Agricultural Research Service of the U.S. Department of Agriculture, whereas Republic research institutes are similar to departments within a State agricultural experiment station. The U.S.S.R. Academy of Sciences research institutes are probably more like U.S. Department of Agriculture regional research laboratories than any other setup. Our National and State academies of sciences do not have the administrative functions that academies in the U.S.S.R. do. Their presidents seem to occupy a position analagous to that of a "vice-president for research" in a United States university.

U.S.S.R. Academy Institutes

The organization of the Dokuchayev Institute of Soil Science was described in the report of a previous technical study group.[4] We did not attempt to learn the organizational details of the Institute of Plant Physiology, which was the other U.S.S.R. Academy of Sciences institute we visited.

All-Union Research Institutes

All-Union institutes have a director, one or two deputy directors, and a scientific secretary. Each institute is composed of a number of laboratories concerned with one phase of the institute's area of research. The All-Union Scientific Research Institute of Fertilizers and Agricultural Soil Science has nine laboratories, each headed by a senior professional man. The laboratories are (1) plant nutrition; (2) microbiology; (3) organic fertilizers; (4) mineral fertilizers; (5) application of fertilizer; (6) mass soil testing for fertilizer recommendations; (7) desert and steppe soil zone; (8) Chernozem soil zone; and (9) other soil zones.

This institute works on fertilizer requirements of crops, fertilizer application methods, and tillage practices on all kinds of soils, including Solonchak and Solonetz. No work is done on production of fertilizers. Several experiment stations and soil testing laboratories are operated by the Institute at locations throughout the U.S.S.R. The Moscow laboratory for soil testing maintains close control over the operations of the field laboratories.

[4] Kellogg, C. E., and others. SOIL AND WATER USE IN THE SOVIET UNION. U.S. Dept. Agr. Unnumb. Pub., 50 pp., illus. 1959.

Approximately 25 hectares of land are used for field testing of fertilizers near Moscow, but the bulk of the 40,000 hectares available for field tests is located at the substations. The total staff of professional people and technicians attached to the institute, including its substations and soil testing laboratories, is about 2,000 persons.

The Kostyakov All-Union Institute of Hydrotechnics and Amelioration in Moscow is concerned with engineering and reclamation of soils. The Institute's Laboratory of Soil Amelioration was established in 1913; most of its work consists of studies of water relations in soils. This includes determination of the laws governing water and salt movement in soils, as well as water use by plants under irrigation, capillary adjustment of soil water, methods of measuring moisture content of soil (the neutron method is currently being investigated), drainage of soils, salinity control, and off-season irrigation to store water in the soil. The Laboratory staff consists of 20 people, which is considered small.

Union Research Institutes

The Middle Asian Scientific Research Institute of Irrigation is an example of a Union research institute that has restricted area responsibilities. Its efforts are confined to problems related to irrigation in central Asia. The institute, which was established in 1925, has 12 laboratories: (1) Amelioration; (2) maintenance of hydroelectric installations; (3) economics; (4) mechanization of amelioration operations; (5) hydrotechnical; (6) wave processes; (7) automation and telemechanics; (8) hydrologic measurements; (9) building materials; (10) soil mechanics; (11) chemistry; (12) pumps.

In addition to the laboratories, the institute has its own machine shops and operates some experiment stations away from Tashkent.

An interesting variation from the usual institute organization was encountered here. This one operates under four "plans": (1) Subject matter studies; (2) contract work; (3) application of results; (4) publication.

Under plan 1, the laboratories work mainly on studies of engineering, methods of amelioration, improvement of maintenance of irrigation systems, improving efficiency of water use, techniques for irrigation, improvement of distribution works, hydrotechnical projects in mountainous areas, improvement of construction methods, design of new pumps, and use of local building materials. Under plan 2, 5,000,000 rubles of contract work on maintenance of irrigation systems, construction methods, design of structures, and related work was done in 1960. This type of work is contracted to the institute by organizations that cannot do it themselves, such as state farms and hydroelectric works. Plan 3 provides for participation in organization and construction of irrigation works to be sure they are made properly—a form of extension service or consulting activity. Plan 4 is the publication of results of the institute's studies.

The staff consists of 550 people, of whom 150 do what is called "pure" research. Thirty-seven of the professional staff have Candidate of Science degrees and two have Doctor of Science degrees.

Republic Academies and Research Institutes

In the Republic organization of research, all research institutes are under the direction of the Republic academy of sciences or academy of agricultural sciences. The Uzbek Academy of Agricultural Sciences is an example of the type of organization used in the academies. This academy, which was established in 1957 when the Uzbek Academy of Sciences was divided into an Academy of General Sciences and an Academy of Agricultural Sciences, has 16 research institutes under it. All research in these 16 institutes of the academy is guided by a presidium of 10 members. Presidium members include the president, vice-president, scientific secretary, and the heads of the three departments of the academy. The three departments are (1) cotton growing; (2) animal husbandry; and (3) agronomy. These departments are responsible for the activities of the research institutes that come within their fields. The Cotton Growing Department, for example, has direction over the Institutes of Cotton Growing, Irrigation, Amelioration, Soil Science, and Agricultural Engineering. Similarly, the Animal Husbandry and Agronomy Departments have institutes under them.

There are 1,300 people on the professional staff of the academy and its institutes, 1,600 to 1,700 assistants, and part-time workers, for a total of about 5,000 persons employed by the academy.

Although the emphasis is on research, some graduate training is conducted by the academy, and this phase of its activities is to be expanded in the future. When we were there, 358 students were doing graduate work. An additional 175 graduate students were to be enrolled in the fall of 1960, and starting in 1961, the academy plans to admit 200 graduate students each year. Students who complete their graduate work at the academy receive their degrees from universities, not from the academy. A strong preference was indicated for the degree-granting university to be from another city, in order to avoid bias for or against the candidate. Some staff members are sent to other cities like Moscow and Kiev to do their graduate work at universities there.

Undergraduate training in the agricultural sciences at three colleges in the Uzbek S.S.R. was under the control of the Academy of Agricultural Sciences until 1959, when it was transferred to a committee on higher education.

We were quite impressed when the president of the academy told us that the academy has more money than it can spend. We did not ascertain whether that situation prevailed in academies of other republics.

In the Tadzhik S.S.R., the Academy of Sciences, which was established in 1951, has 3 departments and 40 institutes, with a total staff of about 4,000, of whom 200 have Candidate of Science or Doctor of Science degrees. The 3 departments of this academy are (1) biology and agricultural science; (2) geology and technical chemistry; and (3) social science.

The Turkmen Academy of Sciences, established in 1950, also has three departments: (1) Technical (chemistry, geology, etc.); (2) biological (botany, zoology, botanical gardens, etc.); (3) soil survey and amelioration (soil science, agronomy, etc.).

In addition, the Turkmen Academy has a subsection of social science, a subsection concerned with the operation of the Kara-Kum Canal, and a council that coordinates research for the Republic. This coordinating council is probably the same as the presidium of the Uzbek Academy of Agricultural Sciences.

As an outgrowth of the disastrous 1948 earthquake, which had its epicenter 25 kilometers east of Ashkhabad and destroyed most of the city, an Anti-Seismic Activity Institute is to be established within the Turkmen Academy.

Individual Republic research institutes are organized into laboratories, headed by a senior professional person, as is the case with other kinds of research institutes we visited. The Institute of Soil Science at Tashkent, in the Uzbek S.S.R., is an example of the way soil research institutes are organized and the kind of work they do. This institute has nine laboratories: (1) Geography and origin of soils; (2) soil salinity; (3) soil erosion; (4) soil physics; (5) soil microbiology; (6) soil chemistry; (7) large scale mapping and appraisal; (8) microelements; (9) soil expeditions.

The institute was established in 1943 for the purpose of studying land resources and improving agricultural conditions, but the Soil Salinity Laboratory, which formerly served all of central Asia, has been in existence since 1919. Until 1960, the institute was part of the Uzbek Academy of General Sciences but is now in the Uzbek Academy of Agricultural Sciences.

The Soil Expeditions Laboratory, which was established in 1959, serves somewhat like a combined extension service and action agency for the institute. It is charged with the preparation of soil maps, including single factor maps designed to improve soil management practices on farms. Laboratory personnel are supposed to advise farm directors on methods of salinity and erosion control, as well as on general soil management.

This institute, perhaps because it is older than other soil research institutes in central Asia, appears to have accomplished more than the others in the way of publication of information on the soils of the Republic. Two comprehensive books on soils, plus numerous reports, have been published thus far, with more scheduled for the future. One book covers soil formation and classification in the central part of the Republic and the second covers the Fergana Valley in the east.

The institute has initiated an interdisciplinary study of means to improve the utilization of soils for cotton production and has selected five farms in the Republic to serve as experimental and demonstration farms. Physical, chemical, and biological problems will be investigated simultaneously on an applied basis.

Institute personnel consists of 56 research workers and 43 research assistants. Seventeen members of the staff have Candidate of Science degrees and three have Doctor of Science degrees. One member is an academician of the Uzbek Academy of Agricultural Sciences.

Other soil science institutes were organized similarly to the Uzbek Institute, with some differences in specialization due to locally important problems. The Institute of Soil Science at Stalinabad in the Tadzhik S.S.R., for example, had laboratories of soil amelioration, physics and chemistry of soils, geography and origin of soils, and wind erosion of deserts and control of desert erosion by revegetation. The Tadzhik Institute planned to add laboratories for radioisotopes and mineralogical analysis to the six laboratories it now has.

An interesting Republic research institute, whose work would appear to be rather far afield from soil salinity, was the Scientific Research Institute of Horticulture, Viticulture, and Winemaking at Tashkent. It turned out, however, that the institute was primarily concerned with fruit and nut production rather than winemaking, and had studies underway on salt tolerance of crops. No work is done on vegetable crops at this institute.

Research conducted at the institute appears to cover nearly the entire field of horticulture, ranging from biology, physics, and agricultural chemistry to plant protection (entomology), orchard management, machinery testing, and winemaking. There are 11 substations of the institute that have about 3,000 hectares of land for experi-

ments. The staff consists of about 300, of whom 38 have Candidate of Science degrees and 4 have Doctor of Science degrees. Eighteen graduate students are studying at the institute, which is part of the Uzbek Academy of Agricultural Sciences.

About 1,700 varieties of crops are being tested here, including 600 varieties of apples and 500 varieties of grapes. Adaptability of fruit and nut crops to both dry and irrigated land is being investigated. Members of the research staff are sent to collective and state farms to advise them on their problems, thereby serving as an extension branch of the institute. We were told that nurseries run by the institute furnish, annually, about 500,000 each of grape, fruit tree, and other rootstocks to collective and state farms.

Soil Classification and Mapping

The Dokuchayev Institute of Soil Science in Moscow is the leading research institute in the Soviet Union for classifying and mapping soils. Experimental stations of the institute are maintained at various places in the Soviet Union, and members of the Moscow staff spend some time at the field stations. Dr. Antipov-Karatayev, for example, who is head of the Department of Physics and Chemistry of Soils and is presently studying the improvement of Solonetz soils, was working at a station near Stalingrad while we were in the Soviet Union. He also advises the Institute of Soil Science at Stalinabad on soil problems in the Tadzhikistan Republic.

The institute prepares maps for collective and state farms that show, in addition to soils, such single factors as pH, potassium, phosphorus, wetness, and snow cover. The scale is usually 1:25,000, and the maps are hand-colored. We tried at every farm visited to obtain at least one copy of such maps but were unable to do so. In fact, although we gained the impression at the Dokuchayev Institute that soil and single-factor maps were available for practically all collective and state farms, we actually saw only one set, which was at the Kuibyshev state farm in the Vakhsh Valley, Tadzhik S.S.R. These maps had been prepared by the Tadzhik Soil Science Institute. Soil maps showing the fertility levels of soils and the distribution of Solonchak and Solonetz soils are also made at the All-Union Scientific Research Institute of Fertilizers and Agricultural Soil Science in Moscow.

We were told that aerial photographs were used in the soil survey program, but we saw only planimetric maps. In the Tadzhik S.S.R., the scale of mapping is 1:10,000 or 1:25,000, and all the irrigated land in the Republic is said to be mapped. Single-factor maps are supposed to be checked periodically to determine whether any changes in such things as available phosphorus, salt, and depth to water table have occurred. In practice, they said, this review is made at about 5-year intervals on a part of the farms.

A mechanically operated soil tube has been developed at the Kostyakov All-Union Institute of Hydrotechnics and Amelioration in Moscow that uses a motorcycle for supplying power. The soil tube, with the handle housing-gear mechanism, is connected to the motorcycle through a flexible drive shaft, which rotates the tube. The tube has an inner diameter of 42 mm. and can be extended to 3 meters in length. The assembly weighs 8 kg. We saw this same unit, complete with motorcycle, in a laboratory at the Stalingrad Agricultural Institute.

The classification of saline soils is based on the following criteria:

Class	Percent salt		Descriptive term
	Chlorides dominant	Sulfates dominant	
1	Less than 0.3	Less than 0.3.	Nonsaline.
2	0.3 to 0.7	0.3 to 0.7	Weakly saline.
3	0.7 to 1.0	0.7 to 1.5	Moderately saline.
4	1.0 to 1.5	1.5 to 2.0	Strongly saline.
5	More than 1.5.	More than 2.0.	Very strongly saline (Solonchak).

Percentage of salt is determined by preparing a 1:5 soil-water suspension, filtering, evaporating the filtrate to dryness, and weighing the residue.

On the actual maps, the distribution of saline soils is shown as the percentage of the delineated area that is covered by these soils. For example, the maps will show areas where less than 20 percent, 20 to 35 percent, etc., of the soils are Solonchak, based on the above criteria.

The soil institutes of the various Republics of the Soviet Union agree concerning the classification of Solonchak and Solonetz soils. Whether this is the result of a government dictum or whether the various soil institutes have agreed upon the classification is something we did not determine. A further classification of saline soils, based on chloride content of the 1:5 extract, was used in the Tadzhikistan and Azerbaijan Republics. In this case, less than 0.03 percent chloride was considered a permissible level, whereas it was considered excessive above that level.

One thing we tried to learn was the criteria the Soviets use to classify Solonetz soils. We

received several different explanations, some of which included the exchangeable-sodium-percentage (ESP) as a criterion, whereas others considered only the structure of the B horizon; still others brought in both concepts. We concluded that the most generally accepted criterion was structure of the B horizon; if the horizon had a well-defined prismatic structure the soil was called a Solonetz. Takyrs, in the Turkmen S.S.R., for example, are not called Solonetz because they do not have a prismatic B horizon even though they may have an ESP of 20 or more. In the Stalingrad area, where Solonetz soils are extensive they do have a prismatic B horizon.

In addition to the classification based on depth to the prismatic layer, a further breakdown is used. Typical Solonetz have an ESP in excess of 20, solontsevati (solonetz-like) have an ESP of 15 to 20, and slabosolontsevati (weak solonetz-like) have an ESP of 15 or less. It appeared that the degree of development of the prismatic structure was the first criterion used in classifying Solonetz soils, with the ESP levels being those that would be expected in the different cases rather than the actual ESP. Soils with prismatic structure in the B horizon but with a low ESP in the horizon are sometimes called "magnesium Solonetz," the theory being that magnesium has replaced sodium on the exchange complex. Since we were told that the exchangeable magnesium level of all soils in the vicinity of Stalingrad was about the same, there is some doubt whether exchangeable magnesium really enters into the classification.

At the Institute of Soil Science in Stalinabad, the head of the Laboratory of Soil Geography, P. A. Kerzum, said that soils containing sodium carbonate are called "black Solonchak." They are not called Solonetz, irrespective of the exchangeable-sodium-percentage, unless they have a prismatic B horizon. The geographer said that soils containing considerable exchangeable sodium in the absence of a prismatic structure in the B horizon *must* be high in soluble salts and are, therefore, Solonchaks. Similar views on the classification of saline-sodic soils were expressed by Academician Volobuyev of the Azerbaijan Institute of Soil Science and Agrochemistry.

All agreed that Solonchaks were soils containing excessive soluble salts. Where sulfates are dominant, a soil is a Solonchak when it contains more than 2 percent salt, based on analysis of a 1:5 soil-water extract. If chlorides are dominant, a salt content of more than 1.5 percent distinguishes the soil as a Solonchak. In practice, the 2 percent limit seems to be generally used. In Stalinabad, P. A. Kerzum said that the use of the term "Solonchak" is restricted to conditions where the salt level is so high that crops will not grow. Saline soils in the arid regions containing less than 2 percent salt are classed as "salty Sierozem."

Soil Chemistry

As indicated previously, Soviet soil scientists usually determine total salinity by weighing the residue obtained upon evaporation of a filtered 1:5 or 1:10 soil-water extract to dryness. The results are expressed as percentage of salt on a dry-soil basis and, as far as we are aware, soil texture or water retention characteristics are not taken into account in relating salt content to plant growth.

American soil scientists recognize that plants growing on saline soils respond to the salt concentration of the soil solution, and that with a given salt content, expressed on a dry-soil basis, the concentration of the soil solution in the field moisture range is inversely related to fineness of texture or water retention capacity. For this reason, most American scientists employ for the determination of salinity an extract obtained at a water content related to the water retention characteristics of the soil, e.g., saturation extract. Moreover, the salt concentration of the extract is determined by measuring its electrical conductivity rather than by weighing the residue obtained upon evaporation. Leading Soviet salinity specialists frown upon the use of electrical conductivity for the measurement of salinity, but we saw this method in use at two institutes and at a soil testing laboratory of a state farm.

Soviet soil scientists attach considerable importance to the compositions of the salts, but the emphasis is on the anion composition. Because the cations undergo exchange reactions with the soil and may influence the chemical and physical properties of the soil markedly, American scientists emphasize the cationic, rather than the anionic, composition of the salts. In particular, the ratio of sodium to calcium plus magnesium is emphasized.

Although Soviet scientists, notably Gapon and Antipov-Karatayev, have published papers on cation exchange equilibrium in soils, we found little evidence that this work is used to predict the effects of irrigation waters on the exchangeable cation composition of soils or to estimate their exchangeable-sodium-percentage from analyses of equilibrium water extracts. This situation is probably owing to the fact that the exchangeable sodium problem appears to be a minor one in Soviet irrigated areas and that the ratio of sodium to calcium plus magnesium in soils and irrigation waters is relatively low and favorable. Moreover, many of the soils contain native gypsum.

For the most part, the methods employed for the determination of various ions appeared to be

the standard wet chemical methods. The use of ethylenediaminetetraacetate (EDTA) for the titration of calcium and magnesium was observed, and at the Institute of Soil Science in Stalinabad we saw a Kupp flame photometer made in The Netherlands that was being used to determine sodium and potassium (fig. 17). This institute also had a polarograph, a spectrograph, and a radioisotope laboratory, as well as pH meters and photoelectric colorimeters. A spectrograph was also demonstrated at the Stalingrad Agricultural Institute. Both spectrographs employed a photographic plate and a densitometer for measuring line intensity. Differential thermal analysis and X-ray apparatus for clay mineral study were observed at the Department of Soil Science and Biology, Moscow State University. This department undoubtedly also had all of the various instruments seen at the Institute of Soil Science in Stalinabad.

There seemed to be considerable interest in chemical determinations of available plant nutrients in soils. Tissue tests were being used in at least one institute visited. Phosphorus was being determined in several ways, depending on the type of information desired. At the Dokuchayev Institute in Moscow and at the Institute of Soil Science in Tashkent, phosphorus was extracted with concentrated HCl. These values, representing more or less total quantities, were used for soil mapping purposes. At other institutes, 1 percent $(NH_4)_2CO_3$ (1:20 soil-water ratio) was used to extract available phosphorus. One percent K_2CO_3 solution (Das method) was used at the Institute of Soil Science and Agrochemistry in Baku for determing organic P, and CO_2 extracts were used at the Institute of Soil Science in Tashkent.

Total nitrogen was determined at the Dokuchayev Institute of Soil Science by the Kjeldahl method. A partial oxidation method for determining available N was being studied at the Institute of Soil Science at Stalinabad, but the method was reported as not too successful.

Exchangeable potassium was being determined by the Kerserov method at the Dokuchayev Insti-

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Figure 17.—Soil laboratory with flame photometer for measuring sodium.

tute and with a 1:30 ammonium acetate extract at the Institute of Soil Science in Tashkent. At one field location we visited chemical quick tests were being used for testing the nutrient status of reclaimed soil.

Soil Physics

Several laboratories dealing with research in soil physics were visited in Moscow and in the central Soviet Asian Republics. At the All-Union Institute of Hydrotechnics and Amelioration in Moscow, we observed a recent development in the use of the neutron method to measure soil moisture and soil density. The moisture probe utilizes a 5 millicurie Ra-Be source positioned at the lower end of the probe; it is similar in many respects to, but smaller than, the Troxell probe developed by C. H. M. van Bavel. A detailed description of the instrument is available in a publication by V. A. Emel'yanov and A. I. Zaytsev.[5]

The density probe uses a cobalt 60 source and is similar in principle to that developed by J. A. Vomicil and later by C. H. M. van Bavel in the United States. The source and detectors are placed in separate holes in the soil, spaced a given distance apart. Another development was the use of gamma absorption to measure the turbidity of water. Here, the source and detector were mounted at opposite ends of a rod on equipment resembling a current meter. A vane is used to keep the assembly oriented in the direction of the current. The delegation was told that this equipment would automatically control equipment to apply deflocculants when a given level of turbidity is reached.

At the same laboratory the delegation observed a single pressure membrane apparatus and several tensiometers being used to measure soil moisture tension. Studies of unsaturated flow in soil were also in progress. It appeared that difficulties were being encountered in fabricating porous cups with adequate bubbling pressure and good transmission characteristics. Techniques and equipment commercially available and in use in many United States laboratories would facilitate the studies observed.

In Professor Kachinsky's laboratory, Department of Soil Science and Biology, University of Moscow, we saw a number of instruments that he and his associates had developed for measuring soil stickiness, field infiltration, particle-size distribution, aggregate stability, bulk density, air permeability, penetration, etc. With some modifications, most of the equipment observed are standard items in most United States soil physics laboratories. The soil stickiness measurement is made by placing 10 cm.^{2} disks made of steel, brass, wood, or plastic in contact with the soil sample. The disks are attached to one end of a beam balance. Weights are added to the other arm until contact between disk and soil is broken. Measurements are made on both disturbed and undisturbed soils.

The water penetration apparatus utilizes a plexiglass cylinder (diameter about 7.5 to 10.0 cm.) with a metal bit attached to the bottom. Field measurements are made by forcing the bit 3 cm. into the soil. A cylinder cover and valve arrangement is provided whereby variable or constant head measurements can be made. At least five measurements are taken at a given site.

The penetrometer is a small spring-loaded device that plunges a probe into the soil. The resistance of the soil is indicated in kilograms per square centimeter in relation to depth. A number of springs with various strengths are provided to handle various conditions.

Bulk density measurements are made by driving steel cylinders having a volume of 100 and 500 cm.^{3} into the soil. The diameter of the cutting head is 1 mm. smaller than the cylinder, to prevent deformation of sample.

Aggregate analyses are based upon Yoder's wet-sieving procedure. The apparatus utilizes a 10-cm. stroke with 50 strokes per minute. Measurements are made on soil samples at field moisture content taken periodically or about five times per season.

At the Institute of Soil Science in Stalinabad, Tadzhik S.S.R., Nickolayev described studies he and his associates conducted on water movement under irrigated and dryland conditions. On irrigated lands, emphasis was placed upon water storage capacities, permeability, and moisture extraction patterns by various crops, particularly cotton, as related to irrigation schedules. Gypsum blocks were used in these studies.

Movement of water in the vapor phase in relation to water regimes on dryland soils was studied by isolating in the soil, gypsum blocks in wire screen containers. Nickolayev claimed that the blocks respond to changes in relative humidity within the range of 70 to 100 percent when buried at various soil depths. Hourly readings are taken two times monthly to delineate zones of condensation. From calibration curves and resistance measurements, the amount of water vapor transported can be determined. On the basis of his results, Nickolayev maintained that condensation is not so much affected by pore diameter or relative humidity as by barometric pressure of the soil air.

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[5] Emel'yanov, V. A., and Zaytsev, A. I. CERTAIN RESULTS OF APPLICATION IN THE U.S.S.R. OF RADIOISOTOPES IN RECLAMATION RESEARCH. Internatl. Comm. Irrig. and Drainage, Ann. Bul., pp. 3–7. 1959. [In English.]

Nickolayev has developed many interesting devices, including a transpirometer. The principle of operation was not apparent from limited discussions available, but evidently many detailed studies relating transpiration to evaporation have been made, using this instrument in conjunction with gypsum blocks. The transpirometer is about 10 cm. high and 5 cm. thick, with a slot in the bottom. The slot is placed over a leaf and a measurement of vapor loss is obtained.

Other procedures developed and demonstrated by Nickolayev and associates include a quick method for determining soil texture based upon rate of capillary rise of water in hand-packed soil columns. Clay samples require about 2,100 minutes and sandy samples 40 minutes to rise to a height of 10 cm. Nickolayev added that the quick method developed does not preclude the use of the pipet method where more precise textural information is needed. Procedures to obtain a laboratory estimate of field capacity on disturbed soil samples were also described. Here water-saturated soil samples are placed upon a dry plaster-of-paris block about 2 cm. thick, covered, and allowed to stand until the sample loses its sheen. The time the sample remains on the block is critical and subject to variability among technicians. Sandy soils require about 2 to 3 minutes and clay soils about 1 hour to lose their sheen. Precision claimed is ± 4 percent by weight, which represented ± 100 to ± 200 $m.^3$ of water per hectare where total water-holding capacity is 5,000 to 6,000 $m.^3$ per hectare.

Hygroscopic coefficients were being determined and related to the wilting percentage to establish the lower limits of available moisture. Low soil moisture tension values used to establish pF curves were obtained on poor quality porous ceramic plates with bubbling pressure of 0.5 bar or less. The quality of moisture retention equipment observed here and at other locations visited was inferior to models commercially available in the United States. Personnel at this institute seemed to be acquainted with some United States publications as evidenced by the complete translation of Baver's textbook, "Soil Physics," a personal achievement of Nickolayev himself.

A soil mechanics laboratory and equipment were observed while visiting the Middle Asian Scientific Research Institute of Irrigation. The equipment to measure soil strength also was seen in Nickolayev's laboratory in Stalinabad.

At the Institute of Soil Science in Tashkent, Uzbek S.S.R., soil structure investigations are under the direction of S. S. Gusek. Primary emphasis deals with the nature of soil structure and how Sierozem or Desert soils in their area can be improved. Materials similar to VAMA (Krilium), and developed in Russia, were reportedly equal to or better than VAMA. Application rates of 0.10 to 0.20 percent, by weight, apparently gave stable structure that outlasted correspondingly untreated soils.

Gusek also was interested in water erosion, and used raindrop techniques developed in Russia, Yoder's wet-sieving techniques, and microscopic techniques to measure and observe aggregate stability. A plastic flume about 2 meters thick and 1 meter long, in which a soil sample can be placed and subjected to the force of flowing water, was on display. We were told that movie cameras are used to record visually changes in structure that occur within the soil sample. Gusek emphasized that to understand the mechanics of water erosion was much more difficult than the mechanics of wind erosion. He also indicated that better methods for evaluation of soil structure are needed, but he had no new concepts to offer. He is interested in water movement as related to moisture storage; has used tensiometers and gypsum blocks to follow moisture changes in soil profiles; and recognizes the problems of stratified soils in relation to field capacity. He does not believe that gypsum block is suitable to measure soil moisture for U.S.S.R. soils, but has hope for the neutron method. In general, he determines soil moisture content gravimetrically.

Three lysimeters used to study reclamation procedures while a crop is growing were observed at the experiment station of the Institute of Soil Science of the Academy of Soil Science of Tadzik S.S.R. The lysimeters were constructed of concrete and had an undisturbed soil profile. The area of each is 3.5 square meters, with a total soil volume of 9 $m.^3$ Water table depth is maintained at 2.5 meters. The walls of the isolated soil block were first coated with bituminous material for waterproofing before installing the concrete walls. The bottom was poured in place. Techniques utilized to assure no leakage were not apparent, but, according to information received, tests indicated that the lysimeters were watertight.

A wind tunnel is used to study wind erosion at the Academy of Science in Ashkhabad, Turkmen S.S.R. Studies conducted are similar to work done by A. W. Zingg and W. S. Chepil at the Wind Erosion Laboratory, Manhattan, Kans. The wind tunnel observed, however, was considerably smaller, and sampling techniques of eroded material in the airstream appeared inadequate. A tank-type vacuum cleaner was connected to the sampling tubes in the wind tunnel, but no provision was readily apparent whereby the velocity of air movement entering the sampling tubes could be adjusted to the velocity of air movement in the boundary layer. In fact, with

the distance of sampling device downstream and windspeeds being used, it appeared that the sampling device may have extended above the boundary layer developed in the tunnel. Under such conditions transformation of wind tunnel soil erosion data to natural field conditions may be misleading.

A sampling device to measure wind erosion under field conditions was observed. The equipment is rigid and lacks the ability to orient the sampling slot in the direction of prevailing winds. Chepil has recently designed such a device, but with a vane that allows orientation regardless of wind direction.

Soil Microbiology and Organic Matter

Although the schedule did not allow a great deal of exploration into areas not closely connected with soil salinity problems, some information was obtained about other fields of research during tours of the laboratories and in speaking with the Soviet scientists. At the Dokuchayev Institute of Soil Science, Academician Tyurin, Director of the Institute, also directs the work of the nitrogen balance laboratory. There, Tyurin's rapid method for the determination of total nitrogen and carbon in soils was demonstrated.

Prof. M. M. Kononova, who is in charge of the section of biochemistry and microbiology, was not present at a meeting with the staff of the Dokuchayev Institute; however, one of her coworkers, K. V. Dyakonova, indicated some of the general areas of research. These include studies of the composition of soil humus and the processes involved in humus formation. For such studies, the laboratory contained an infrared analyzer and electrophoresis equipment. The importance that is attached to organic matter in soil formation and soil fertility was apparent from a display of detailed soil maps, which gave the depth of humus as well as such factors as available phosphorus and soil acidity. Professor Kononova is the author of a book on soil organic matter that will soon be available in English translation.

Other laboratories were also involved in the study of soil organic matter. At the Institute of Soil Science, Stalinabad, changes in soil organic matter under different cultural conditions were being studied. At the Institute of Soil Science, Tashkent, a study was being made of the microbiological conditions and the forms of humus in the irrigated regions.

In view of the fact that there has been considerable publicity concerning the use of bacterial fertilizers in the Soviet Union, the scientists and farm directors in the areas visited were questioned in regard to this practice. At none of the state or collective farms visited were bacterial fertilizers being used. At some of the scientific institutions, it was stated that bacterial fertilizers were being used only on a limited experimental basis in the particular areas where the institutions were located. Since most of the soils in the irrigated areas are low in organic matter, it is not surprising that phosphorus-releasing cultures, "Phosphobacterin," which allegedly increase the rate of release of phosphorus from organic forms, are not used. On the other hand, the fact that the soils are low in nitrogen and organic matter should encourage the use of nitrogen-fixing cultures, or "Azotobacterin," if such a practice is effective. Numerous observations of mineral fertilizers being applied in the field indicated a strong reliance on such fertilizer to supply the necessary nutrient elements to the plants.

In connection with the use of Phosphobacterin, cultures that were obtained from the Soviet Union during a visit by a group of United States soil scientists in 1958 have since been tested extensively in the greenhouse, in the laboratory, and at field locations in Alaska, Montana, Minnesota, North Dakota, and Texas.[6] Except for a slight increase with tomatoes in one experiment, there have been no significant increases in phosphorus uptake by plants due to Phosphobacterin inoculation.

At the All-Union Institute of Agro-Forestry Amelioration, located near Stalingrad, a large-scale composting procedure was observed in the field. Here, 300 tons of manure plus a quantity of phosphate had been plowed down in a small area and allowed to decompose. The resulting compost was bulldozed into a large pile and later applied to fields at the rate of 12 to 20 tons per hectare. It was emphasized that 13 tons of living plasma developed during the composting process of the 300 tons manure through the growth of micro-organisms, and that application of the compost was an important means of increasing the microbial population of the soil. It was stated that an application of 12 tons of compost was equal to 25 to 30 tons of manure, and that a kilogram of compost contained about 2 grams of mineral nitrogen. No estimate was given of the value of the composting procedure in comparison to direct field application of manure plus phosphate.

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[6] SMITH, J. H., and others. EVALUATION OF PHOSPHOBACTERIN AS A SOIL INOCULANT. Soil Sci. Soc. Amer. Proc. 25: 109–111. 1961.

Plant Physiology

Considerable emphasis is being placed on the effects of drought, extremes of temperature, and salinity on plant development and growth at the Institute of Plant Physiology in Moscow. Most studies are being conducted in well-instrumented, environmentally controlled plant-growth chambers and greenhouses (fig. 18). The research is based on the idea that resistance of plants to extremes in environment is not static and is the result of past genetic changes. Workers at this laboratory believe that it is possible to increase tolerance of plants to unfavorable conditions by treatments applied in early stages of growth, i.e., by "hardening" of seed. The resistance of plants to drought, high temperature, and excess salts is being related to the colloidal and chemical properties of the protoplasm.

Resistance to Drought and High Temperatures

To "harden" the plant, seed is soaked in water for a specified length of time, after which it is dried. Three cycles of soaking and drying have been tried, but only a single treatment was reported to be necessary. Tomato and wheat seed are soaked until they contain 45 percent water (takes 24 to 48 hours for tomatoes), and sunflower seed is allowed to soak to a moisture content of 65 percent. Plants produced from hardened seed were reported to yield more than those from unsoaked seed when grown under droughty or high-temperature conditions. The effectiveness of the treatment is related to an increase in cell metabolism (increase in energy level), increased viscosity and elasticity of the protoplasm, as well as increased bound water, greater osmotic pressure, a change in cell structure, a greater number of stomata, and an increase in leaf area. In general, it was recommended that the treatment should be applied to each new lot of seed each year before planting. Reference was made, however, to the case of an experiment with sunflowers in which drought tolerance persisted for six generations. It thus was stated that new varieties can be developed

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FIGURE 18.—Plant research in greenhouse at Institute of Plant Physiology, Moscow.

by the hardening process, and that the technique should be of use to plant breeders.

Specific Ion Effects on Plants and Salt Resistance

It was stated that the types of salts are of importance when dealing with salinity. Main emphasis is being placed on the effects of Cl^- and $SO_4^=$ which were reported to change the physiological and anatomical properties of plants. Cotton growing in the presence of $SO_4^=$ has small cells, more stomata, better conduction of water through the plant, greater transpiration and rate of photosynthesis, more cooling and lower leaf temperature, better root systems, and greater water uptake than plants growing in the presence of excessive chloride. The adverse effects of salinity on plants are classified as follows:

Salt content of soil (percent total salts)	*Effect on plants*
0.3 to 0.7	Slight.
0.7 to 1.0	Medium, if chlorides predominate.
1.0 to 1.5	Medium, if sulfates predominate.
1.0 to 1.5	High, if chlorides predominate.
1.0 to 2.0	High, if sulfates predominate.
2.0	No cultivated plants grow.

In connection with the higher limits set for $SO_4^=$ salts, it should be pointed out that, at equivalent concentrations on a weight basis, $SO_4^=$ salt solutions have a considerably lower osmotic pressure than Cl^- salt solutions. Thus, a 1.0-percent solution of NaCl has about the same osmotic pressure as a 1.5-percent solution of Na_2SO_4.

It was stated that the main cause of poor growth of plants under saline conditions is the toxic effects of ions, especially Cl^-, and not osmotic effects. Cells of plants growing under highly saline conditions were reported to accumulate excessive amounts of NH_4^+, putrescein ($NH_2(CH_2)_4NH_2$), and many other organic products that result from degradation of protein and act as toxins to plants.

P. A. Genkel of the Institute of Plant Physiology in Moscow indicated that he had increased salt tolerance of plants by using the "hardening" process. Seeds are soaked in dilute NaCl, $MgSO_4$, or Na_2CO_3 solutions under specified conditions, rinsed, and dried. Increased yields were reported from such seed planted in saline soils. It was also stated that Cl^--hardened seed were effective in Cl^-- but not in $SO_4^=$-saline conditions. Sulfate-hardened seed were prepared for $SO_4^=$-salinity conditions, and $CO_3^=$-hardened seed for soils containing $NaHCO_3$ and Na_2CO_3. Success with this method in one field trial of cotton was reported, but the method is not being used generally on farms. Greenhouse experiments involving the growth of sorghum and cotton produced from hardened seed were underway.

Miscellaneous

Studies of the effects of gibberellic acid at various soil nitrogen levels were being conducted on corn in a greenhouse experiment at the All-Union Scientific Research Institute of Fertilizers and Agricultural Soil Science in Moscow. Observation of the plants revealed considerable response to treatments, but details of the experiments were not explained. Similar studies at the Institute of Soil Science and Agrochemistry in Baku were being conducted by D. T. Guseynov. He was investigating the effects of oil byproducts on the growth of plants. Both seed and foliar treatments were being studied. Reference was made to the use of a carboxylic acid ($C_{15}H_{24}O_2$), which was said to be more effective in promoting growth than gibberellic acid.

At the Stalingrad Agricultural Institute, the Field Crops Section was subjecting corn seed to infrared radiation before planting. It was indicated that the treatment controlled seed-borne fungal diseases and stimulated early germination and growth. The seed is subjected to infrared for 1 to 2 minutes and is just slightly warm to the touch as it leaves the conveyor belt.

Education

Of considerable interest and perhaps of greatest significance were the large numbers of institutes and academies dedicated to higher education and research; the large number of students; the large number of books available and book stores on the city business streets (popular and very technical books); the number of people everywhere reading books; the completeness of the libraries of foreign language journals and texts found in the institutes; the great effort being expended by the Soviet peoples in learning a foreign language.

The Soviet Union is now embarking on a program to strengthen the curricula in universities, teaching academies, and institutes by introducing more "practical" training, which means more laboratory and on-the-job training. This entails extending the college period from 5 to 5½ years. Increased emphasis on practical studies appears to stem from the announced concern of Prime Minister Khrushchev over the preference college graduates have for desk jobs rather than working with their hands.

At the Timiryazev Agricultural Academy in Moscow, which has 6,000 undergraduates and 500 graduate students, undergraduate and graduate degrees are offered in the fields of agronomy, zootechnics (animal husbandry), agricultural economics, agricultural engineering, mechanical engineering, and hydroengineering and amelioration. Within these fields, there are further breakdowns in specialities. In agronomy, for example, five kinds of specialists are trained: (1) Field agronomy, (2) plant breeding, (3) plant protection, (4) soil science and agrochemistry, and (5) horticulture and vegetable growing.

The degree comparable to our Bachelor of Science is Specialist of Higher Qualification and an agronomist would receive the degree of Agronomists of Higher Qualification. At the graduate level, the degree comparable to our Master of Science is Candidate of Agricultural Science (C.A.S.) or, as at Moscow State University, the Candidate of Science (C.S.) degree. Moscow State University also grants the Doctor of Science (D.S.) degree that is awarded to scientists who have demonstrated research ability and have made a notable contribution to their field.

The school year is from September to May. After the second year, students are granted 1 month of vacation and must perform 2 months of practical work on experimental stations or on collective or state farms between school terms. There are two semesters in the school term. Entering students, who generally have 10 years of elementary and secondary schooling, must pass an entrance examination unless they are in the upper 5 percent of their graduating class in high school. Courses offered at the Timiryazev Academy for agronomy students include the following:

First year	General agronomy, mathematics, organic chemistry, analytical chemistry, geology, physics, botany, foreign languages, and general courses such as philosophy and literature.
Second year	Plant physiology, soils, physical chemistry, colloidal chemistry, meteorology, foreign language, and general courses.
Third year	Agronomy (crop and soil management), agricultural chemistry, animal physiology, animal nutrition, genetics, entomology, and plant pathology.
Fourth and fifth years.	Field-crop growing, vegetable-crop growing, forage crops, breeds of livestock, economics, statistics, farm management, and bookkeeping in agriculture.

The first semester of the fourth year and the second semester of the fifth are spent at the academy, taking course work and preparing a diploma thesis. In between these two semesters, students work on experimental stations and farms, carrying on projects related to their specialization and gathering material for their theses. Specialization begins in the third year. Soil science and agrochemistry students, for example, concentrate on advanced soils courses during the third, fourth, and fifth years but do take other courses. Before the Specialist of Higher Quali-

fication degree is granted, a student is usually required to defend his diploma thesis, although some faculties at Moscow State University permit the substitution of a comprehensive oral examination on subject matter for the thesis defense. In 1960, the Timiryazev Agricultural Academy granted 70 Specialist of Higher Qualification degrees and six C.A.S. degrees in soil science and agrochemistry.

At Moscow State University, more emphasis is placed upon courses in soils (for soils majors) during the third, fourth, and fifth years than at the Timiryazev Academy. Soils students take a 45-day trip to the Black Sea between the second and third year to study soils and agriculture from Moscow to the sea. They are required to make a report on the trip when they return. Between the subsequent academic years, they participate in soil-mapping expeditions for 2 months each summer. Soil mapping, in this instance, refers more to the preparation of single-factor maps showing the levels of such things as available phosphorus and soil salinity than to soil surveying as we think of it.

Sixty students are admitted annually to the Biology-Soil Department for the 5-year course, which is to be extended to 5 years and 4 months, in line with the new government policy. Graduates with the Specialist degree are assigned positions in research institutes and as soil mappers in the various Republics, or are permitted to do graduate work toward the C.S. or the C.A.S. degree. The research upon which the C.S. or C.A.S. degree in soils is granted can be done at teaching academies and universities or at soils institutes throughout the Soviet Union.

Stalingrad Agricultural Institute is an agricultural college with an enrollment of 2,500, including 63 graduate students. Thirty to forty percent of the students are girls. The Institute has four departments: agronomy, zootechnics (animal husbandry), mechanical engineering, and hydropower engineering. Their curriculum has been extended to 5½ years. The institute also has 1,500 correspondence students in addition to the full-time students.

The Polytechnic Institute at Stalinabad, Tadzhik S.S.R., has four departments: hydropower, construction of buildings, technology of cotton fiber, and maintenance of road transport. There are 2,500 students enrolled in day, evening, and correspondence courses, of which 35 percent are girls.

Classes are held in the evening and laboratory work is performed in the morning, with afternoons left free. All students are said to take 480 hours of classwork in mathematics, which is approximately equivalent to 8 semesters of a 4-hour course. After the fourth semester, only theory courses are taught until the last year, when practical work is done in the preparation of the diploma thesis. All full-time students receive a stipend of 300 to 450 rubles per month, depending upon their year in school. Dormitories are free and meals in the cafeteria at the institute are low-priced. Students who fail to pass the examination in defense of their diploma thesis are assigned a job for 1 year, after which they may return for another examination. When they receive their Specialist degree and are assigned to a job, they may not be discharged from that job for at least 3 years.

State and Collective Farms

In the course of the tour, the U.S. Soil Salinity Delegation visited many state and collective farms in the Soviet Union to observe the techniques being employed and the results being obtained in desalination and reclamation of salt-affected soils. Although concentrating on questions of soil salinity, the group was able to observe to some extent the general operation of the farms as well. A description of two state farms and one collective farm of the many visited is given below. Although these farms are by no means typical of Soviet farms generally, they are representative of those superior farms to which the tour by the study group was confined.

Malek State Farm

The group traveled to this state farm on July 17, 1960, and was met by the director, S. A. Bochkarov. The Malek state farm is located in the center of the Golodnaya Steppe, 120 km. south of Tashkent in Tashkent Oblast, Uzbek S.S.R.

Land

This state farm has a total area of 5,000 hectares. Of this total, 4,300 hectares are being used for crops. The rest is still undergoing reclamation. A farm of this size, said the director, was considered a large farm for this area a few years ago, but, as a result of the amalgamation of collective farms (begun in 1950) and a general trend toward larger state farms, it is now only an average-size farm in this region. In addition to the 5,000 hectares in the farm itself, an additional 1,000 hectares is rented in the nearby Kazakh S.S.R. This rented land is used to produce fodder, which the Malek state farm feeds to its livestock herds.

Soils

The soils of the Malek state farm are alluvial, deposited by the Syr Darya River. They are mixed red and gray soils, with no clear boundaries between the soil types. This mixture results from the nature of the erosion at the headwaters of the Syr Darya River. This river originates from melting snow in the Pamir Mountains; the resulting runoff waters erode different levels of the mountain soils during different seasons of the year; hence, the varying nature of the silts carried by the river at different times during a year and the mixture of the alluvial deposits on the Golodnaya Steppe.

Water Use

All the 4,300 hectares of tilled land in the Malek state farm are irrigated. The irrigation water is channeled to the farm and to the surrounding area from the Syr Darya River. Irrigation water is applied two or three times a year on most of the land in the farm, but up to five times a year on some fields. The entire area of the farm is also leached periodically. One thousand hectares of the land receive leaching three times a year, 600 are leached twice a year, and the remainder only once. The rate of water application is 2,200 to 2,500 cubic meters per hectare for each leaching operation.

Crops

The main crop grown on this farm is cotton. All the cotton grown is a variety developed in the U.S.S.R., which is similar to the American upland varieties. In 1959, 2,000 hectares were planted to cotton, and the yield was 30.5 centners of seed cotton per hectare. On completely reclaimed land, the yield was as high as 40 to 50 centners per hectare. On the saline soils where reclamation is in early stages, the yields were as low as 9 centners per hectare of seed cotton. All the cotton produced is sold to the state and at prices determined by the central authorities. For the cotton sold in 1959, the farm received 65 rubles per centner of seed cotton.

In addition to cotton, the farm also produces alfalfa, corn, fruit, and sugar beets. In 1959, it had 1,400 hectares in alfalfa from which the yield was 60 centners of dry weight per hectare. The farm also had 200 hectares in corn from

which 240 centners of green silage per hectare were harvested. (Most of the corn grown in the U.S.S.R. is harvested as silage, not as grain, owing to the generally shorter growing season in the country, as compared to the United States.) Last year, the farm had 75 hectares in fruits of various kinds and 30 hectares in sugar beets. The sugar beets were grown as fodder for livestock.

This year (1960), the farm has 400 hectares of land planted to corn, of which 200 are planted with alfalfa and will be harvested as green fodder. An additional 100 hectares will also be harvested green, to be fed as roughage, and the remaining 100 hectares will be allowed to ripen and will be harvested as dry grain. Both hybrid and open-pollinated varieties of corn have been planted.

Crop Rotation

Soviet state and collective farms typically use a long-term crop-rotation system. The Malek state farm uses a 9-year rotation consisting of cotton for 5 years, alfalfa for 3 years, and major leveling and general amelioration of the soil for 1 year. Light leveling is done yearly, prior to the planting season.

Fertilizer Use

Superphosphate and ammonium nitrate were mineral fertilizers mentioned by the director as being used on the farm. Fifty-four kilograms per hectare of superphosphate are applied to alfalfa. Airplanes are used to apply the fertilizer, and, using this method, 150 hectares per day can be fertilized at a cost of 12 rubles per hectare.

Livestock

Although the Malek state farm is in an irrigated area and the main emphasis is on crops, the farm does maintain some livestock and delivers the products to the state, as it does its crop output. The farm has a herd of 800 cattle, including 250 milk cows. In 1959, the average milk yield per cow was 3,500 kg., or a total output of 875,000 kg. This was sold to the state at 115 kopeks (1.15 rubles) per liter. (In calculating yield, the Soviets used a weight unit, kilograms, but the milk is sold to the state on a volume basis.) The director said all the milking is done mechanically. The farm has a poultry flock of 21,000 birds and also keeps a small herd of hogs. This year (1960) the plan is to produce a total of 12 tons of pork, poultry, and beef (dressed weight). Half will be sold to the state, and half will be retained for consumption on the farm.

Personnel

There are 600 families living on the Malek state farm, with a total population of 3,300. Of this number, 900 are employees of the farm. Of this labor force, 500 workers are employed in the cotton brigades. The delegation was not given average wage figures for the whole labor force, but it was told that workers in cotton brigades received an average of 680 rubles per month. Presumably, the workers in the cotton brigades receive a higher-than-average wage, since they produce the main "money crop" on this farm. Tractor drivers, the labor elite of any Soviet farm, earn an average of 1,100 rubles per month.

Farm Income

In the planned economy of the Soviet Union, the state sets the prices at which products will be purchased from the state and collective farms and thus directly influences the profit or loss on sales by the farm. In 1959, the Malek state farm made a total profit of 1½ million rubles. On the cotton crop, an industrial crop for which the state pays well, the clear profit was 3 million rubles, but the farm lost money on other produce delivered to the state procurement centers. For example, the price received for milk was 115 kopeks (1.15 rubles) per liter, while the cost of producing milk on this farm was 130 kopeks per liter.

Kuibyshev State Farm

The delegation visited this state farm on July 13, 1960, and was met there by the director of the farm, Yu. D. Voronin. The Kuibyshev state farm is located in the fertile Vakhsh Valley about 150 km. south of Stalinabad. It was started on drained and reclaimed marsh land after the Second World War. This farm is one of only six state farms in the cotton growing area (Vakhsh Valley) of the Tadzhik S.S.R. Most cotton producing farms in the Republic are collective farms.

Land

The farm has an area of 5,000 hectares of arable land. All this is under crops, and it is all irrigated. The source of water is the Vakhsh River, which flows through the valley and is the source of irrigation water for the whole area. This river has a very low salt content, only one-half gram per liter, which minimizes the salinity problem and reduces the cost and effort of salinity control.

Soils

The soils on this farm are fine sandy loams and well-suited to irrigation. The main problem in reclamation was salinity. The area is one of ancient irrigation that left the soils saline. The soil was reclaimed by first building deep drains, then leaching by growing irrigated rice. Using this method, the state reclaimed the soils in 1½ to 2 years.

Crops

The main crop grown on the farm is cotton. In 1960, 3,500 hectares were planted to this crop. The cotton varieties used are all Soviet-developed but are similar to the long staple Egyptian cotton from which they originated. The average yield for the farm is 28 to 30 centners of seed cotton per hectare—slightly higher than the average yield for the Vakhsh Valley of 28 centners per hectare. Corn is grown as a fodder crop on this state farm. The average yield is 50 to 60 centners per hectare of dry grain or 500 to 700 centners per hectare of silage.

Fertilizers

On this farm, the only chemical fertilizers used are phosphate and nitrogen. No potassium fertilizer is applied, because there is no potassium deficiency in this area. Nitrogen is applied at the rate of 120 to 140 kg. per hectare.

Income

The Kuibyshev state farm has an annual income of 20 to 25 million rubles. This figure was given to the study group as "clear profit" but it probably was total receipts, as the highest total income on any farm visited by the study group (other than this one) was 15 million rubles, on the Leninism collective farm in Mary Oblast, Turkmen S.S.R.

Livestock

The farm has 2,000 bacon-type hogs and 1,200 dairy cattle. They feed no beef cattle and have no sheep on the farm, except for sheep maintained by the farmworkers on their private plots.

Personnel

The farm has 2,500 workers on its payroll. The average wage paid to the workers is 750 rubles per month. Tractor drivers, the highest paid workers, earn 1,100 rubles per month. In addition to their wages, each worker has a plot of land of one-eighth hectare for his own use from which he may consume or sell the produce as he sees fit. Each worker, according to the director, also has the right to use the farm's machinery to cultivate his land.

Leninism Collective Farm

The Soil Salinity Delegation visited the Leninism collective farm on July 8, 1960, and was received by the chairman, Mr. Kondymov. This collective farm is located near the city of Mary, in Mary Oblast, Turkmen S.S.R.

Land

The farm has a total area of 2,300 hectares. Of this area, 80 percent, or 1,840 hectares, is under irrigation and is used for crops. The rest of the land is natural pasture and wasteland.

Soils

The area in the vicinity of Mary is an area of desert land, much of which has been reclaimed and irrigated. On the Leninism collective farm, the soils are mainly fine sandy loam, well-suited to irrigation.

Water Use

The source of water for irrigation and leaching on this farm is the Kara-Kum Canal, the giant irrigation canal now under construction that will bring water from the Amu Darya River to a vast region in the Kara-Kum Desert south of the Amu Darya.

Crops

The main crop raised on this farm is cotton. In 1959, it accounted for 12 million of the 15 million rubles received by the farm from the sales of its produce to the state. The average yield was 23 centners per hectare of seed cotton. The cotton grown on this collective farm is planted in rows half a meter apart, which, the group noted, was the common spacing between rows in cottonfields on Soviet irrigated cotton farms. As is the general practice throughout the Soviet Union, the cotton is topped. This is done to reduce vegetative growth and to facilitate harvesting.

In addition to cotton, the farm has 30 hectares of vineyards. The grape crop is used in part for making wine to be consumed locally and in part is consumed as fresh fruit. The farm also has 250 hectares planted to alfalfa. It raises most of its own fodder but sometimes buys fodder produced at other farms from the state.

Livestock

The farm has various types of livestock. There is a flock of 10,000 Karakul sheep, which are sold to the state to be used in making Karakul wool products. The farm also has a herd of 300 cattle, 100 of which are dairy cattle and 200 of which are raised for meat. There are also 400 bacon-type hogs and a flock of 25,000 poultry. The farm has its own incubation station for poultry.

Income

All the produce delivered to the state is sold on contract. These contracts are arranged prior to the sowing of the crop in the spring. They specify only the price to be paid for the product, not the amount to be delivered, according to the chairman. Thus, there is no penalty for failure to supply a specified amount of product. The farm is obliged to deliver the goods to a procurement point with its own transportation, however. In 1959, the income of the farm was 15 million rubles, all from its sales to the state. The year before (1958), the total receipts had been 23 million rubles, but this was unusually high. The average income of the farm, the study group was told, is 16 to 17 million rubles per year.

Personnel

There are 600 families living on the Leninism collective farm, with 1,000 collective farm members (the farm labor force) and a total population of 2,300. All the families live in one village. Each has a land allotment of one-fourth hectare for its own use.

The farm labor force is divided into 10 brigades, each of which is responsible for a certain area of the farm. Machinery is assigned to each of these bridgades from a central machinery depot on the farm, and the workers are responsible for this machinery during the time they are using it.

This collective farm recently initiated a type of piecework system as a basis of labor payments, rather than the old labor-day system. Under the old system, workers were paid so much per unit of time worked, with pay differentials per unit of time according to the skill or effort required to perform the job. A tractor driver, for example, was considered more skilled than a herdsman and, consequently, would receive more labor days per unit of time worked. Under the new system, workers are paid so much per unit of land worked, regardless of the amount of time required to do the job. Pay differentials are still based on the skill or effort required, but the time spent on the job is no longer a factor in wage payments.

The minimum earnings of collective farm members, said the chairman, are normally 600 rubles per month. Members can draw advances of up to 50 percent of their anticipated earnings per month, even though the farm accounting is done only at the end of the year and a final tabulation of individual member earnings is not done until that time.

Appendix

Electrical conductivity and estimated sodium-adsorption-ratio of irrigation, drainage, and miscellaneous waters [1]

Republic	Source	Location	Electrical conductivity (mmhos./cm. @ 25° C.)	Sodium-adsorption ratio
	Irrigation Waters			
Azerbaijan	Araks River	Canal, 135 km. from Baku	0.80	1.9
Turkmen	----	Irrigation ditch, near Ashkabad	.46	1.0
	Amu Darya	Kara-Kum Canal, near Mary	.60	1.2
Tadzhik	Vakhsh River	Farm ditch, Kuibyshev state farm	.50	----
Uzbek	Syr Darya	Farm ditch, Malek state farm	.65	1.2
	Drainage Waters			
Azerbaijan	Main collector drain from Shirvan Steppe.	93 km. from Baku	350	138
	Tile drain	Mugan Station	110	12
	Open collector drain	do	25	25
Turkmen	Open collector drain	Northwest of Mary	8.0	7.6
	do	Near Chardzhev	8.0	----
	do	do	7.0	----
Tadzhik	Groundwater from open pit	Kuibyshev state farm, Vakhsh Valley	610	----
	Open collector drain	Collective farm, Vakhsh Valley	1.9	----
	do	do	1.6	----
	do	Experimental leaching farm, Vakhsh Valley.	14	----
Uzbek	Open collector drain	State farm, Malek-Hungry Steppe	3.5	----
	Miscellaneous Waters			
Federated	Tap water	Leningradski Hotel, Moscow	.27	.5
Turkmen	do	October Hotel, Ashkabad	1.45	2.6
Azarbaijan	Caspian Sea	Baku Harbor	20	32

[1] Measurements made in the field by members of the committee, using a test kit and procedures described in U.S. Dept. Agr. Cir. 982, "Tests for Salinity and Sodium Status of Soil and of Irrigation Water."

Electrical Conductivity of saturation extract and estimated exchangeable-sodium-percentage of soil samples [1]

Republic	Sample Location	Description	Saturation Extract		Estimated exchange-able-sodium-percentage
			Electrical conduc-tivity (mmhos./cm. @ 25° C.	Sodium-adsorption-ratio	
Azerbaijan	Mugan Station	Virgin soil	35.0	56	45
		Irrigated soil	.8		
Turkmen	Semennik, near Mary	Fallow soil; high water table	125	-----	-----
	State farm near Mary	Takyr soil	50	46	40
Uzbek	Malek state farm, Hungry Steppe.	Saline area being reclaimed	27	7.2	8

[1] Measurements made in the field by members of the committee, using a test kit and procedures described in U.S. Dept. Agr. Cir. 982, "Tests for Salinity and Sodium Status of Soil and of Irrigation Water."

Conversion Table

1 kilometer	=0.62137 mile
1 meter	=39.37 inches
1 centimeter	=0.3937 inch
1 millimeter	=0.03937 inch
1 inch	=2.54 centimeters
1 liter (kilogram)	=1.0567 quarts
1 liter of liquid	=2.2046 pounds
1 cubic meter	=1.308 cubic yards
1 centner	=220.46 pounds
1 metric ton	=2,204.6 pounds
1 hectare	=2.47 acres
1 acre	=0.4047 hectare
In 1960—	
1 kopek	=0.25 cents
1 ruble	=25 cents

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